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03 Human Reproduction

1. Introduction :

- To continue its own race, an organism by the process of reproduction, produces offsprings like its own.
- Humans are sexually reproducing and viviparous.
- In sexual reproduction the organisms produce male and female gametes which on combining, develop into a new individual.
- **The reproductive organs /sex organs are of two types-**

Primary/Essential Sex Organs :

- These are the organs which form the gametes, testes in males & ovaries in females.
- The male gamete is spermatozoon (pleural-spermatozoa). The female gamete is ovum.

Secondary/Accessory Sex Organs :

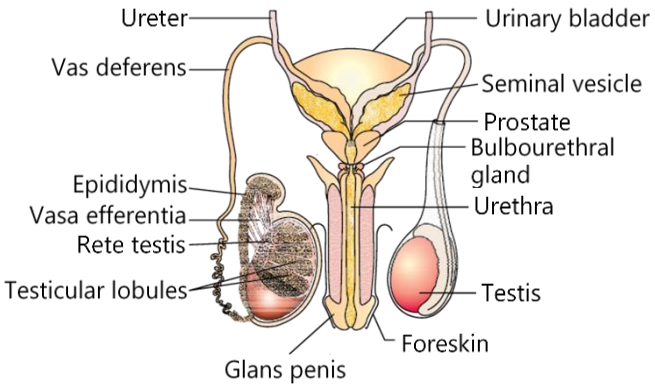
- These organs form the passage for the gametes and help in the union of male & female gametes.
- In male these include epididymis, vas deferens, seminal vesicles, prostate, bulbourethral glands, penis etc. In female these organs are fallopian tube, uterus, vagina, bartholin gland etc.

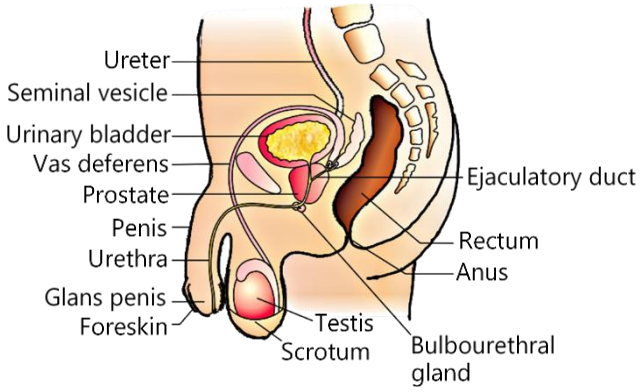
Development of Sex Organ :

- During intra uterine life (IUL) testis & ovary develop from mesoderm. They develop in abdominal cavity. At the time of birth, testes descend down into scrotal sac but ovaries remain in abdominal cavity.

2. The Male Reproductive System :

- The male reproductive system is located in the pelvis region. It includes a pair of testes along with accessory ducts, glands and the external genitalia.
- The male sex accessory ducts include tubuli recti, rete testis, vasa efferentia, epididymis, vas deferens, ejaculatory duct and urethra. These ducts store and transport the sperms from the testis to the outside through urethra.
- The male accessory glands include paired seminal vesicles, a prostate and paired bulbourethral glands.





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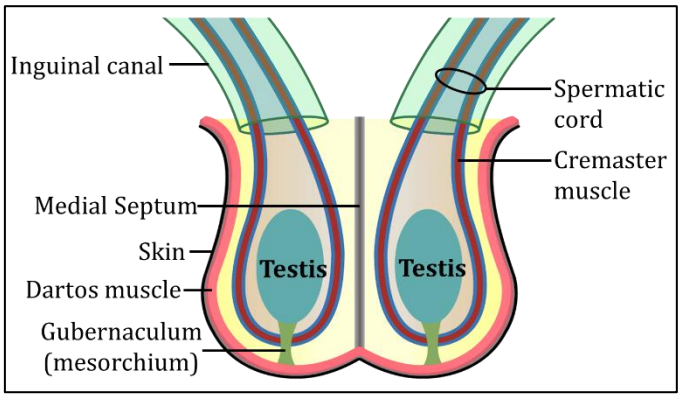
- In man, one pair testes are the main or primary reproductive organ. Size 4-5cm × 2-3cm and oval in shape
- Both testes are located in a small bag like structure situated below & outside the abdominal cavity called as scrotum or scrotal sac. The temperature of scrotum is 2 – 2.5°C lesser than body temperature, necessary for spermatogenesis.
- Internally, scrotum is lined by dartos muscle and spermatic fascia. Dartos muscle helps in regulation of the temperature with in the scrotum. During cold season, it becomes contracted & during warm season, it becomes relaxed.



- Each testis is attached to the wall of scrotum through a group of flexible fibres collectively called as Gubernaculum or Mesorchium.
- Each testis is attached to the wall of the abdominal-cavity through a cord termed as the Spermatic cord. Spermatic cord passes through the inguinal canal. This cord is made up of cremaster muscle & spermatic fascia. Cremaster muscle helps in the elevation of testes. Contents of the spermatic cord are vas deferens, gonadal veins, gonadal arteries, nerves and lymphatics.
- Scrotum is connected to the abdominal cavity through a passage termed as inguinal-canal. Through this canal the testes descend down into the scrotal-sacs at the time of birth. When the testes does not descend to reach the scrotum but remain in abdominal cavity at the time of birth this conditions is called undescended testes or cryptorchidism. Such testis cannot develop and function properly and may develop malignancy.
- **Orchiopexy :** When the undescended testes are brought into scrotal sac by surgical process during childhood this process called as orchiopexy.

(A) Internal Structure of Testis :

- Testis is covered by dense covering which consist of three coats. Outer most is tunica vaginalis. Middle coat is tunica albuginea & inner most is tunica vasculosa.
  - **Tunica vaginalis** has a parietal & visceral layer. It covers the whole testis except its posterior border from where the testicular vessels & nerves enter the testis.
  - **Tunica albuginea** is a dense, white fibrous coat covering the testis all around. The posterior border tunica albuginea is thickened to form vertical septum called the Mediastinum testis.
  - **Tunica vasculosa** is the inner most vascular coat of the testis lining testicular lobules.
- Each testis has about **250** compartments called testicular lobule
- Each testicular lobule has 1 to 3 **seminiferous tubules** (in which sperms are produced hence its called functional unit of testes), which join together at the apices of the lobules to form **tubuli recti** which enter the mediastinum. Here they form a network of tubules called as **rete testis**. Rete testis fuse to form 10 to 20 efferent ductule called as **vasa efferentia**. These ductules come out from upper posterior surface of testis & open into **epididymis**.

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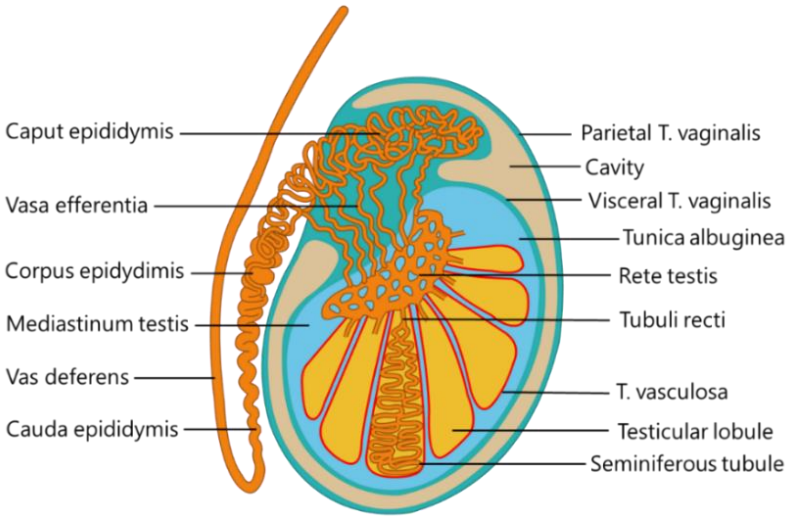
NOTE : Total number of seminiferous tubules in each testis is about 750 to 1000.

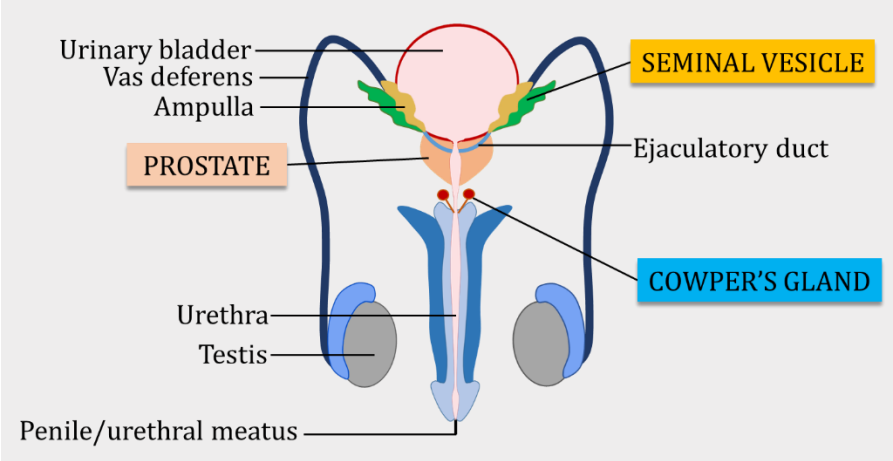
- Each lobule has 1 to 3 seminiferous tubules
- Total number of seminiferous tubules in each testis is about 750 to 1000.
- Seminiferous tubules join together to form straight tubules or tubuli recti which enter the mediastinum.
- Here they form a network of tubules called as rete testis. Rete testis fuse to form 10 to 20 efferent ductule called as vasa efferentia or ductuli efferentes. These ductules come out from upper dorsal (posterior) surface of testis & open into common tubules, which get highly coiled to form epididymis or ductus epididymis. **This epididymis is responsible for functional maturation of sperm**.
- Liberation of sperms from testes is called **semination**.

(B) Epididymis & Vas Deferens :

- Epididymis is responsible for functional maturation of sperm and can store sperms for up to 1 month. Epididymis has 3 parts :
  (i) Caput epididymis - Upper, highly coiled part
  (ii) Corpus epididymis - Middle part
  (iii) Cauda epididymis -Basal, least coiled part



- Vas deferens arise from cauda epididymis and enters inside the abdominal-cavity from the scrotal-sac. Terminal dilated part of vas deferens are called ampulla.
- The wall of epididymis and vas deferens is made up of 2 layers - outer circular muscle layer and inner epithelium. The sperms reach the abdomen due to the pulsations/contractions of the circular muscles.
- Vas deferens run upward & enter the abdominal cavity. Both vas deferens coil around the ureter of their respective sides and then dilate to form ampulla.
- Ampulla of Vas deferens of each side receives the seminal vesicle of that side. The vas deferens now forms ejaculatory duct and opens into prostatic urethra. 1 pair of seminal vesicles are situated on dorso-lateral side of urinary bladder.
- The urethra originates from the urinary bladder and extends through the penis to its external opening called urethral meatus.



(C) Accessory Reproductive Glands :

- The substances secreted by the accessory reproductive glands do not form gametes but help in reproduction, these are –

1. Seminal Vesicle :-

- Internally, it is lined by glandular epithelium which secretes seminal fluid. This is lubricating, transparent and jelly like substance, which makes 60–70% part of semen. It is slightly alkaline (pH 7.3). Fructose is found in seminal fluid, it acts as fuel to sperm. This fluid also contains fibrinogen, prostaglandins, etc.

2. Prostate Gland :-

- This gland is located below the urinary bladder. It is unpaired and made up of 5 lobes in man. Each lobe opens into prostatic urethra through many fine apertures. It secretes slightly alkaline prostatic fluid which is milky, thick, sticky or jelly like. It makes about 30% part of semen and helps in sperm activation. The secretion of prostate gland has calcium, clotting enzyme, profibrinolysin, etc.

3. Cowper's Gland :-

- It is a pair of glands found on lateral sides of urethra. It is also called as bulbourethral gland. It is situated in membranous part of urethra & opens into penile urethra. It secretes transparent, slimy, jelly like fluid. It is slightly alkaline (pH 7.2). This destroys the acidity of the urethra and cleans it for the movement of sperms. It also helps in the lubrication of the penis.

Semen :

Semen = Sperm + Accessory reproductive gland fluid Volume = 3 to 4 ml.

pH = 7.3

Normal sperm count 20 to 120 million/ml.

- **Oligospermia** sperm count & less than 20 million/ml.
- **Azoospermia –** either absence or near absence of sperms.
- **Asthenospermia –** reduced motility of sperms in semen
- **Teratospermia –** sperms with abnormal morphology

Note :- The human male ejaculates about 200 to 300 million sperms during a coitus of which, for normal fertility, at least 60 per cent sperms must have normal shape and size and at least 40 per cent of them must show vigorous motility.

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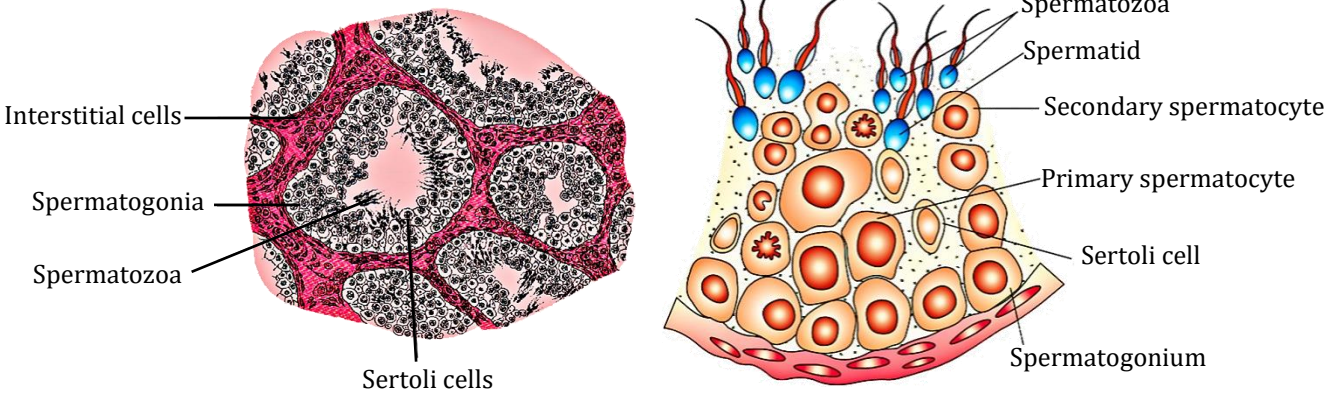
(D) Histology of Seminiferous Tubules :-

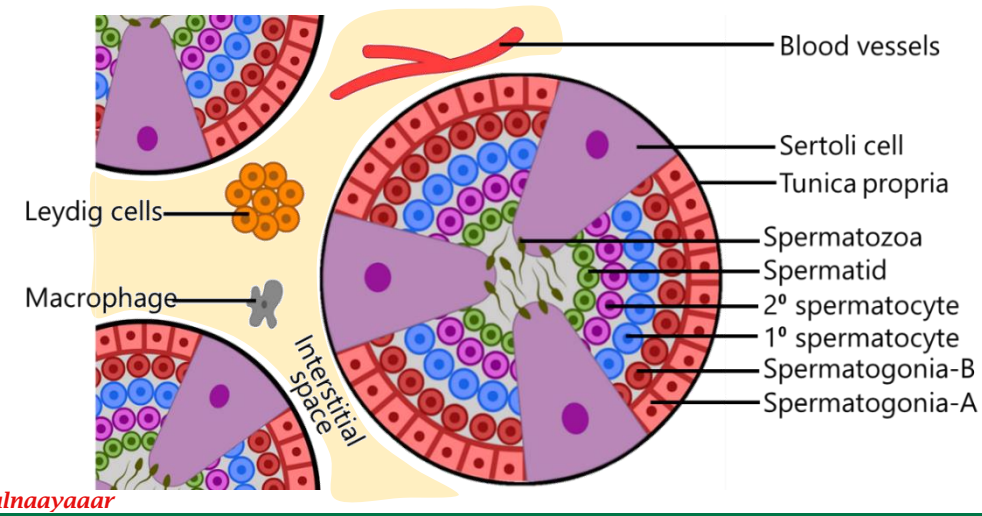


- Outer surface of seminiferous tubules is composed of white fibrous connective tissues called as tunica propria while inner surface is of cuboidal germinal epithelium. This epithelium is made up of spermatogenic cells which forms sperm by spermatogenesis.
- Some columnar cells are found in between the layer of germinal epithelium called as Sertoli cells (these occur in mammals)

Functions of Sertoli cells :

- Provide nutrition to germ cells, so they are also called as sustentacular or nurse cells.
- Phagocyte the injured or dead sperm cells.
- They are the basis of blood testis barrier.
- Produce inhibin and Anti Mullerian Hormone.
- FSH acts on the Sertoli cells and stimulates secretion of some factors which help in the process of spermiogenesis.
- Produce Androgen Binding Protein (ABP) that concentrates testosterone.

- Some endocrine cells are found between seminiferous tubules in inter-tubular space, these are called as interstitial or Leydig cells. These cells secrete androgens (testosterone). The testosterone from Leydig's cells enter the seminiferous tubules by diffusion under the effect of ABP & promotes spermatogenesis.
- Other immunologically competent cells are also present in the interstitial space.



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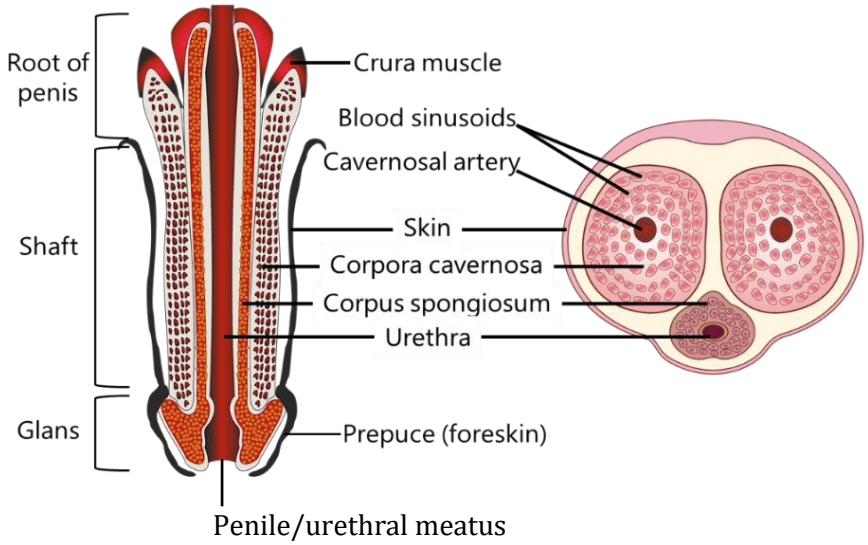
(E) Penis :

- The penis is the male external genitalia and an erectile copulatory/intromittent organ (Organ of copulation), made up of special tissue (Erectile tissue).
- Root of the penis contains a muscle called crura muscle.



Body of Penis :

- It is composed of three longitudinal cylindrical masses of erectile tissue.
- These masses are, the right and left corpora cavernosa and a median corpus spongiosum.
- The two corpora cavernosa do not reach the end of the penis. Each of them terminates under cover of the glans penis.
- The corpus spongiosum continues further, its terminal part is expanded to form a conical enlargement called the glans penis. Throughout its whole length it is traversed by the urethra.
- The glans penis is covered by a loose fold of skin called as prepuce or foreskin. A special type of sebaceous gland is found on the prepuce called preputial gland which secretes oily secretion called smegma. Removal of prepuce by surgery is called is circumcision.
- External opening of penis is called penile/urethral meatus.

Erection of Penis :

- Erection of penis is purely vascular phenomenon and is controlled by Parasympathetic nervous system.
  It occurs due to increase of blood supply, due to dilation of penile arteries causing enlargement and hardening of penis.
- During this time the muscles of Crura are relaxed.

Ejaculation :

- **Liberation of sperms from body of male is called ejaculation.** Sympathetic nervous system is responsible for ejaculation. after ejaculation, penis becomes flaccid.

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BEGINNER'S BOX-1 THE MALE REPRODUCTIVE SYSTEM

1. Which one is a primary sex organ?
(1) Scrotum (2) Penis (3) Testis (4) Prostate gland

2. Which of the following is a secondary sex organ?
(1) Testis (2) Ovary (3) orchiopexy (4) Vas deferens

3. In mammals, maturation of sperm take place at a temperature :-
(1) equal to that of body (2) higher than that of body
(3) lower than that of body (4) at any temperature

4. Partitions of testis develop from :-
(1) tunica albuginea (2) tunica vasculosa
(3) tunica vaginalis (4) rete testis

5. Vas deferens arises from:-
(1) cauda epididymis (2) caput epididymis
(3) corpus epididymis (4) rete testis

6. Testosterone is secreted by the :-
(1) Leydig's cells (2) Sertoli cells (3) spermatogonia (4) All of these

7. Which cells are found in between spermatogonia ?
(1) Germinal cells (2) Sertoli cells
(3) Epithelial cells (4) Lymphatic space

8. Formation of sperms occurs in :-
(1) rete testis (2) seminiferous tubules
(3) Both (1) & (2) (4) mediastinum testis

9. Tunica vaginalis is found in :-
(1) Ovaries of female (2) Testis of male (3) Vagina of female (4) None

10. The functional unit of testis of man is :-
(1) tunica albuginea (2) tunica vaginalis
(3) Seminiferous tubules (4) rete testis

11. Middle layer that covers testis in male is?
(1) Parietal tunica vaginalis (2) Visceral tunica vaginalis
(3) Tunica vasculosa (4) Tunica albuginea

12. Which is unpaired gland in male reproductive system of human?
(1) Bartholin gland (2) Seminal vesicle
(3) Prostate gland (4) Cowper's gland

13. Common duct formed by union of vas deferens and duct from seminal vesicle is :-
(1) urethra (2) tunica-vasculosa
(3) ejaculatory duct (4) spermatic duct

14. Medical condition in which sperm count is less than 20 million/ml, is called?
(1) Oligospermia (2) Azospermia (3) Asthenospermia (4) Teratospermia

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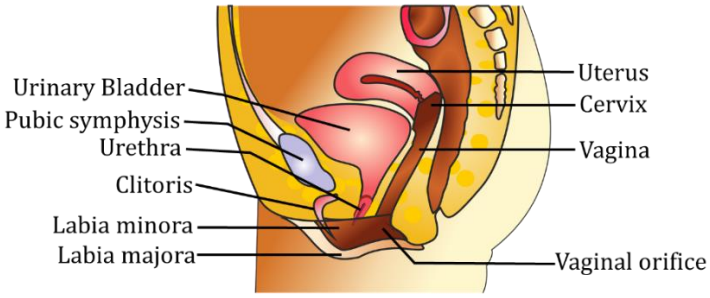
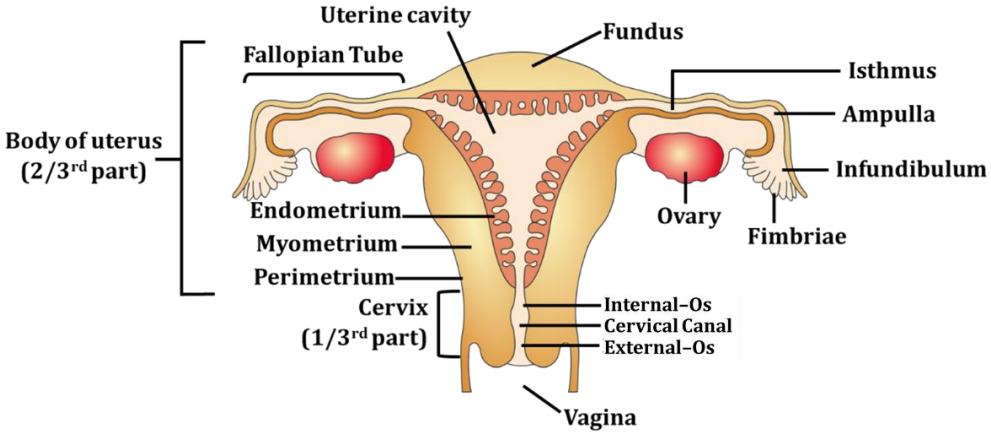
3. Female Reproductive System :-

- **The female reproductive system consists of a pair of ovaries along with a pair of oviducts, uterus, cervix, vagina and the external genitalia located in pelvic region. These parts of the system along with a pair of the mammary glands are integrated structurally and functionally to support the processes of ovulation, fertilisation, pregnancy, birth and child care.**



1. A pair of ovaries is the main or primary sex organ of female reproductive system and **produce the female gamete (ovum) and several steroidal hormones (ovarian hormones).**
2. Both ovaries are located in abdominal cavity.
3. **Each ovary is about 2 to 4 cm in length and is connected to the pelvic wall and uterus by ligaments. Each ovary is covered by a thin epithelium which encloses the ovarian stroma. The stroma is divided into two zones – a peripheral cortex and an inner medulla.**
4. Female secondary sex organs are 1 pair fallopian tube, 1 uterus and 1 vagina and 1 pair Bartholin glands.
5. **Each fallopian tube is about 10-12 cm long and extends from the periphery of each ovary to the uterus.**



6. The lateral end of fallopian tube, which closer to the ovary is funnel shaped and called as infundibulum.
7. Its fimbriated and terminal end bears aperture called as abdominal ostium which opens into peritoneal cavity.
8. Fimbriae help in collection of the ovum after ovulation. The part medial to the infundibulum is called ampulla, it is a thin-walled dilated part of tube. Fertilization takes place in the ampulla.
9. The part medial to ampulla is called isthmus. The most medial part of this tube situated in the uterus is called intramural or interstitial part of tube.
10. During ovulation, the ova are released in the peritoneal cavity, due to this it is called coelomic egg.
11. The part medial to ampulla is called isthmus. The most medial part of this tube situated in the uterus is called intramural or interstitial part of tube. During ovulation, the ova are released in the peritoneal cavity, due to this it is called coelomic egg.

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(A) Uterus :

- Uterus is single and called womb. **It is supported by ligaments attached to the pelvic wall.**
- It is piriform (inverted pear) shape, the upper expanded part is called as body or fundus while lower cylindrical part is called as cervix. The cavity of cervix is called cervical canal which along with vagina forms the birth canal.
- On internal surface of cervix, 2 types of constrictions are found which form the Os–cervix.
  - The body of uterus communicates with the cervix through opening called internal Os.
  - The cervix communicates with the vagina through an opening called external Os.
- The uterus open into a fibromuscular & non-glandular tube-like organ called vagina (female copulatory organ).

Histology of Uterus :

i. **Perimetrium:**
   - It is the outermost thin layer covering the uterus.

ii. **Myometrium:**
   - It is the middle layer of thick smooth muscles.
   - Longest smooth muscles of the body are found in the walls of uterus during pregnancy.

iii. **Endometrium:**
   - It is the innermost & glandular layer.
   - It undergoes cyclic changes during menstrual cycle.
   - In the uterus, embryo gets attached to the endometrium.

Note : The endometrium undergoes cyclical changes during menstrual cycle while the myometrium exhibits strong contractions during delivery of baby.

(B) Vulva :

- Vulva means external genitalia of female. It includes mons veneris, labia majora, labia minora, clitoris, hymen, vestibule & related perineum.
- **Mons veneris (mons pubis):** It is a cushion of fatty tissue or of subcutaneous connective tissue, lying in front of pubis & is covered by pubic hairs in adult female.
- **Labia majora:** Vulva is bounded on each side by the elevation and fleshy folds of skin & subcutaneous tissue. Its inner surface is hairless. Outer surface is covered by sebaceous gland, Sweat gland & hair follicles. It is homologous with the scrotum in the male.
- **Labia minora:** They are two thin folds of skin present just within the labia majora. Lower portion of minora fuses across the midline & form a fold of skin called fourchette.
- **Clitoris:** It is a tiny finger - like structure which lies at the upper junction of the two labia minora above the urethral opening. It is made up of two erectile bodies (corpora cavernosa). The skin which covers the glans of clitoris is called clitoral hood or prepuce. Clitoris is a homologous to the penis in the male.
- At the terminal part of vagina the urethra opens separately, so they form a common chamber called vaginal vestibule or urogenital sinus.
- The vulva has following openings:
  - **(i) Urethral Opening** – Lies on anterior end
  - **(ii) Vaginal Orifice** – Lies on posterior end. It is incompletely closed by a septum of mucous membrane called hymen.

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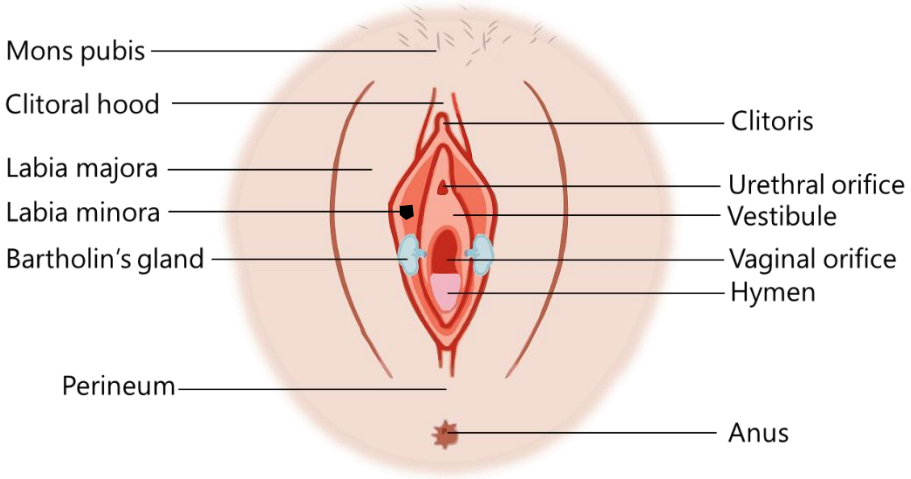
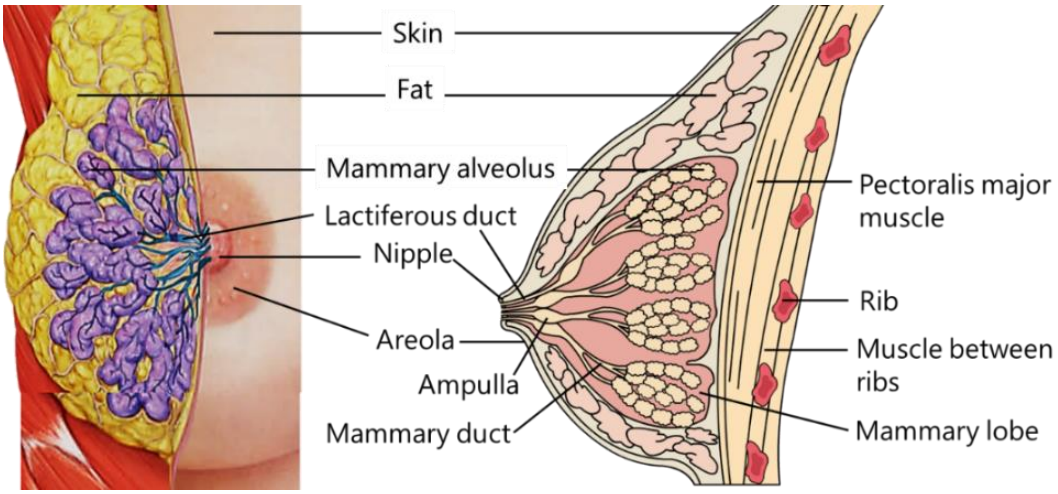
(ii) **Opening of Bartholin's Ducts:** These are opening of one pair bartholin's /greater vestibular glands situated on lateral side of vagina. They secrete alkaline fluid during sexual excitement. Bartholin Gland is homologous to Cowper's gland of male.



Note: The hymen is often torn during the first coitus (intercourse). However, it can also be broken by a sudden fall or jolt, insertion of a vaginal tampon, active participation in some sports like horseback riding, cycling, etc. In some women the hymen persists even after coitus. In fact, the presence or absence of hymen is not a reliable indicator of virginity or sexual experience.

(C) Mammary Gland (Breast) :

- A functional mammary gland is characteristic of all **female** mammals.
- The mammary glands are paired structures (breasts) that contain glandular tissue and variable amount of fat.
- The glandular tissue of each breast is divided into 15-20 mammary lobes containing clusters of cells called alveoli. The cells of alveoli secrete milk, which is stored in the cavities (lumens) of alveoli.
- The alveoli open into mammary tubules. The tubules of each lobe join to form a mammary duct. Several mammary ducts join to form a wider mammary ampulla which is connected to lactiferous duct through which milk is sucked out.
- Mammary glands produce a nutritive fluid, milk for the nourishment of young ones. Milk protects the young ones from various infections up to some months after birth.



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- The mammary glands of the female undergo differentiation during pregnancy and starts producing milk towards the end of pregnancy by the process called lactation. This helps the mother in feeding the new-born.
- The milk produced during the initial few days of lactation is called colostrum which contains antibodies (IgA) absolutely essential to develop resistance for the new-born babies. Breastfeeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

Path way of milk flow in a mammary gland :

Alveoli or acini → Mammary tubule → Mammary duct → Mammary ampulla → Lactiferous duct → Out (through nipple)

BEGINNER'S BOX-2 THE FEMALE REPRODUCTIVE SYSTEM

1. The female reproductive system consists of :-
(1) a pair of ovaries (2) a pair of oviducts (3) uterus (4) all of these

2. Vagina of the female reproductive system is a :-
(1) primary sex organ (2) essential sex organ
(3) secondary sex organ (4) Both (1) & (2)

3. Development of foetus takes place in :-
(1) vagina (2) uterus (3) ovary (4) oviduct

4. Lower narrow end of uterus is called :-
(1) Urethra (2) Cervix (3) Clitoris (4) Vulva

5. In uterus, middle layer made up of thick smooth muscle is called?
(1) Perimetrium (2) Myometrium (3) Endometrium (4) cervix

6. The uterus open into a fibromuscular & non-glandular tube-like organ called :-
(1) Cervix (2) Ampulla (3) Isthmus (4) Vagina

7. Bartholin's glands occur in :-
(1) females and help in vestibular lubrication
(2) females and produce oestrogen for regulating secondary sexual characters
(3) males and form liquid part of semen
(4) males and produce alkaline fluid for neutralising urethral acidity.

8. Abdominal ostium is the aperture present in :-
(1) oviduct (2) fimbriated fallopian funnel
(3) ovary (4) cloaca

9. Correct sequence of different layers of uterine wall is (respectively from outside to inside) :-
(1) Perimetrium → Endometrium → Myometrium
(2) Myometrium→ Perimetrium → Endometrium
(3) Perimetrium → Myometrium → Endometrium
(4) Endometrium → Myometrium → Perimetrium

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10. Clitoris is present at the upper junction of :-
(1) Labia majora (2) Mons pubis (3) Perineum (4) Labia minora

11. Which of the following is not related to vulva?
(1) Mons-veneris (2) Clitoris (3) Labia majora (4) Epididymis

12. Which of the following openings are present in vulva?
(1) Urethral opening (2) Vaginal orifice
(3) Opening of bartholin's ducts (4) All of these

13. The glandular tissue of both breast is divided into-
(1) 10-15 mammary lobes (2) 15-20 mammary lobes
(3) 30-40 mammary lobes (4) 50-60 mammary lobes

14. The mammary glands are paired structures (breasts) that contain-
(1) fat and muscle
(2) muscle and bone
(3) muscle and blood vessels
(4) glandular tissue and variable amount of fat

- The reproductive events in humans include:
  - ❖ **Gametogenesis** – formation of gametes, sperms in males and ovum in females.
  - ❖ **Insemination** – transfer of sperms into the female genital tract.
  - ❖ **Fertilisation** – fusion of male and female gametes, leading to formation of zygote.
  - ❖ **Blastulation** – formation and development of blastocyst.
  - ❖ **Implantation** – attachment of blastocyst to the uterine wall.
  - ❖ **Gestation** – further embryonic development.
  - ❖ **Parturition** – delivery of the baby.

4. Gametogenesis :

- **The primary sex organs – the testis in the males and the ovaries in the females–produce gametes, i.e., sperms and ovum, respectively, by the process called gametogenesis**
- GnRH, FSH, LH regulates gametogenesis. Besides this hormone vitamin E is also essential for gametogenesis.
- Deficiency of vitamin E leads to sterility. Vitamin A is also required for the formation of healthy gametes.
- Gametogenesis is divided in three stages:
  (i) Multiplication phase
  (ii) Growth phase
  (iii) Maturation phase
- Spermatogenesis is the formation of spermatozoa, whereas oogenesis is the formation of ova. Both spermatozoa and ova originate from primordial germ cells or PGCs, which are extra-Gonadial in origin.
- Spermatogenesis occurs in the seminiferous tubules of the testes and oogenesis occurs in the follicles of ovary. Formation of gametes starts at puberty.

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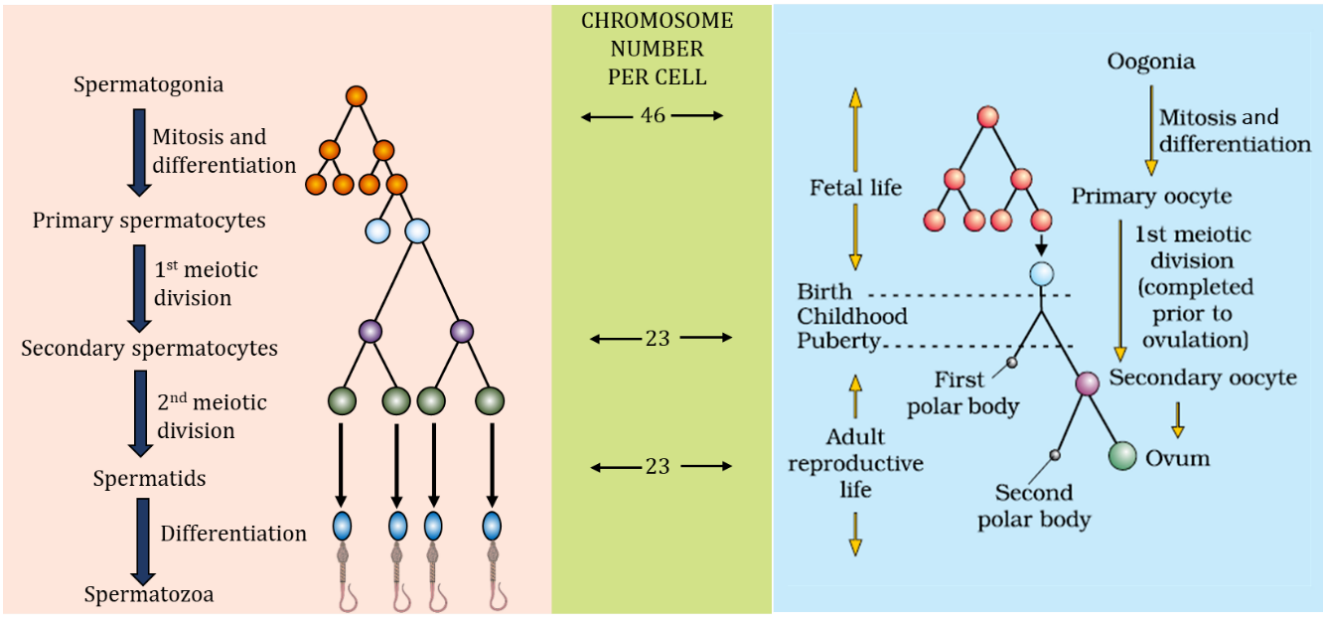

(A) Spermatogenesis :

- The process of formation of spermatozoa in the seminiferous tubules of testis. The wall of seminiferous tubules is lined by cuboidal spermatogonia (male germ cells derived from primordial germ cells) and columnar Sertoli cells.
- At puberty spermatogonia divide to form spermatozoa and Sertoli cells provide nourishment to dividing & developing germ cells.
- Sertoli cells form 'blood testes barrier' and protect the sperm from immune system of the body. Sertoli cells function as an endocrine gland which secretes.
  (i) Inhibin hormone: It gives negative feedback to pituitary gland (mainly) and hypothalamus.
  (ii) Androgen binding protein: It concentrates testosterone in seminiferous tubules to aid spermatogenesis.

Spermatozoa are formed in the wall of the seminiferous tubules of the testes.

A. The spermatogonia (type A) or germ cells (44 + X Y) divide mitotically, to give rise to more spermatogonia of type A and also spermatogonia of type B.

B. The spermatogonia (type B) (44 + XY) enlarge, to form primary spermatocytes.

C. The primary spermatocytes (44 + XY) now divide so that each of them forms two secondary spermatocytes. This is the first meiotic division: it reduces the number of chromosomes to half.

D. Each secondary spermatocyte has 22 + X or 22 + Y chromosomes. It divides to form two spermatids. This is the second meiotic division and this time there is no reduction in chromosome number.

E. Each spermatid (22 + X or 22+Y) gradually changes its shape to become a spermatozoon. This process of transformation of a circular spermatid to a spermatozoon is called **spermiogenesis**.

F. In human beings maturation phase is the longest phase of spermatogenesis.

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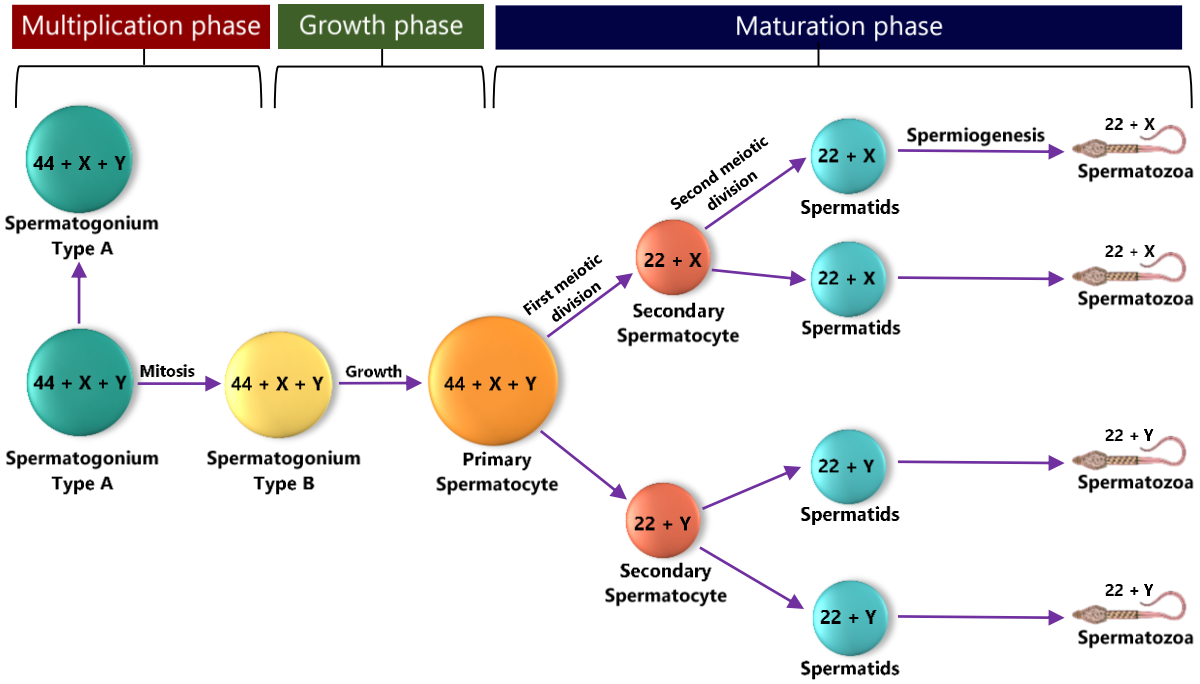
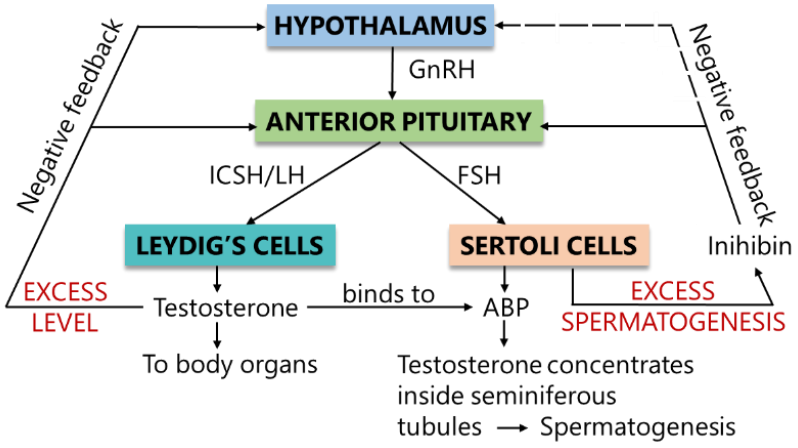


Sperms are liberated from Sertoli cells of seminiferous tubules by the process called spermiation.

(B) Male Reproductive Hormones :

- Spermatogenesis starts at the age of puberty due to significant increase in the secretion of gonadotropin releasing hormone (GnRH).
- GnRH then acts at the anterior pituitary gland and stimulates secretion of two gonadotropins – luteinising hormone (LH) and follicle stimulating hormone (FSH). LH acts at the Leydig cells and stimulates synthesis and secretion of androgens. Androgens, in turn, stimulate the process of spermatogenesis. FSH acts on the Sertoli cells and stimulates spermatogenesis.



FSH: Binds with FSH receptors attached to the Sertoli cells in seminiferous tubules. This causes these cells to grow and secrete various spermatogenic substances and androgen binding proteins **(ABP).**

LH/ICSH: It stimulates the Leydig cells to secrete testosterone.

Inhibin: It is secreted by Sertoli cells in response to excess spermatogenesis. The inhibin gives a negative feedback to the anterior pituitary (Mainly) and hypothalamus (Negligible), this results in suppression of synthesis and release of FSH (Spermatogenesis decreases).

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Testosterone: Secreted by Leydig cells. It is essential for :

(1) Sperm production

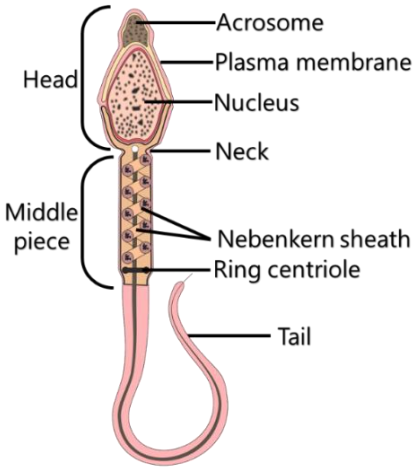
(2) Development of secondary sexual characters

(3) It also gives –ve feedback to hypothalamus and anterior pituitary in its excess concentration to supress GnRH, LH release.

(4) It is secreted in foetal stage in as low as 30 ng/ml plasma concentration to cause descent of testis in last trimester of intrauterine life.

Note: 65-74 days are required to complete the cycle of spermatogenesis in human being.

(C) Structure of Sperm :



It is a microscopic structure composed of a head, neck, a middle piece and a tail. Plasma membrane envelops the whole body of sperm.

HEAD : The sperm head contains an elongated haploid nucleus, the anterior portion of which is covered by a cap-like structure, acrosome. Acrosome is filled with lytic enzymes called sperm lysins that help in fertilization of ovum.

NECK : It contains a proximal & distal centriole (or Basal body). An axial filament begins just behind distal centriole & passes through the middle piece and extends into the tail.

MIDDLE PIECE : It is also called as the energy chamber. It contains numerous spirally arranged mitochondria (Nebenkern sheath), which produce energy for the movement of tail that facilitate sperm motility essential for fertilisation.

Ring centriole (function unknown) is present at distal end of middle piece.

TAIL : The longest part of sperm. Sperm moves by help of tail. Distal centriole, present in neck, acts as basal body and produce axoneme.

Note : The human male ejaculates about 200 to 300 million sperms during a coitus of which, for normal fertility, at least 60 per cent sperms must have normal shape and size and at least 40 per cent of them must show vigorous motility.

(D) Oogenesis :

- The process of formation of a mature female gamete is called Oogenesis.
- Like spermatogenesis, oogenesis process also can be divided into three stages:
  (i) Multiplication phase (ii) Growth phase (iii) Maturation phase

(i) Multiplication Phase :

- During embryonic development stage primordial germ cells or gamete mother cells repeatedly divide by mitosis to form large number of diploid oogonia in each foetal ovary, no more oogonia are formed and added after birth.

(ii) Growth Phase :

- Like spermatogenesis, in this process oogonia grow in size and form primary oocytes.
- The growth phase is the longest phase in oogenesis in oviparous animals.
- During growth phase size of egg increases many times. Yolk and cortical granules are formed during this phase.

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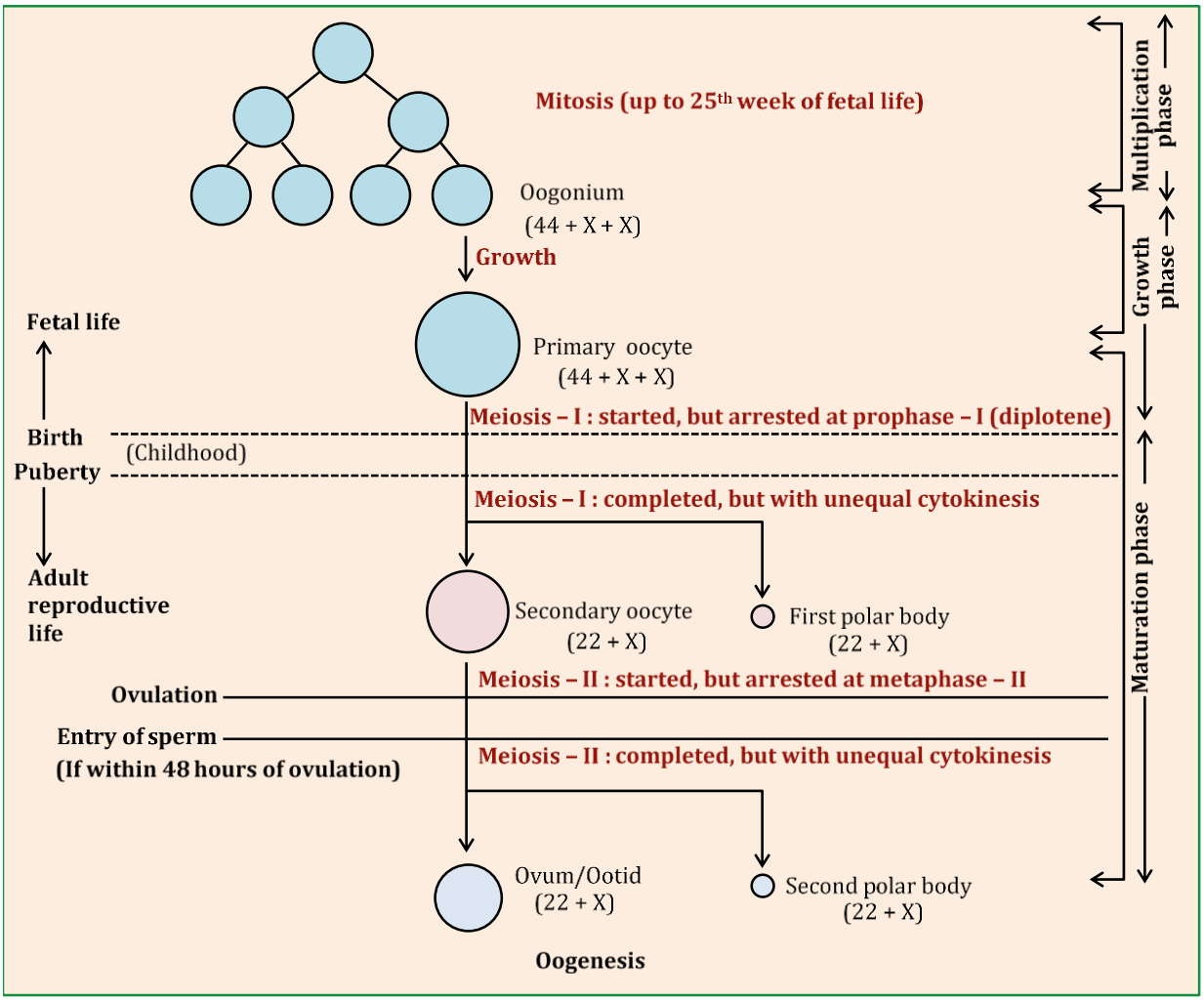
(iii) Maturation Phase :

- It is the longest phase in humans.
- In contrast to males the initial steps in egg production occur prior to birth. By the time the foetus is 25 weeks old, all the oogonia that she will ever produce, are already formed by mitosis. These diploid cells develop into primary oocytes, begin the first steps of the first meiotic division, proceed up to diplotene (prophase-I) and then stop any further development. The oocyte grows much larger and completes the meiosis I, forming a large secondary oocyte and a small polar body that receives very little amount of cytoplasm but one full set of chromosomes.
- First polar body may undergo degeneration due to lack of cytoplasm or may divide. Polar body is, therefore, formed merely to get rid of unwanted chromosomes.
- Whereas the secondary oocyte proceeds as far as the metaphase stage of meiosis II. However, it then stops advancing any further, it awaits the arrival of the spermatozoa for completion of second meiotic division.
- Entry of the sperm restarts the cell cycle breaking down MPF (Metaphase promoting factor and turning on the APC (Anaphase promoting complex) which results in completion of meiosis II. Secondary oocyte retains bulk of the nutrient rich cytoplasm of the primary oocyte and becomes Ovum/Ootid. A small second polar body is also formed.
- The centriole of oocyte degenerates at the time of second maturation division hence centriole is absent in ovum.



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Some important differences between oogenesis and spermatogenesis are :-

(1) One primary spermatocyte gives rise to four spermatozoa whereas, one primary oocyte forms only one ovum.

(2) When the primary spermatocyte divides, its cytoplasm is equally distributed between the two secondary spermatocytes formed. However, when the primary oocyte divides, almost all its cytoplasm goes to the daughter cell which forms the secondary oocyte. The other daughter cell (first polar body), receives half the chromosomes of the primary oocyte, but almost no cytoplasm.

Note :- Vitamin E is essential for gametogenesis. Deficiency of vitamin E leads to sterility. Vitamin A is also required for the formation of healthy gametes.

BEGINNER'S BOX-3 GAMETOGENESIS

1. This process of transformation of a circular spermatid to a spermatozoon is called :-
(1) Spermiogenesis (2) spermatogenesis (3) insemination (4) maturation

2. Longest phase of spermatogenesis is :-
(1) Multiplication phase (2) Growth phase
(3) Maturation phase (4) Germinal phase

3. How many sperms are formed by one primary spermatocyte?
(1) 4 (2) 3 (3) 2 (4) 1

4. Acrosome formation in spermatogenesis occurs in which stage ?
(1) first meiotic division (2) second meiotic division
(3) growth phage (4) spermiogenesis

5. Acrosome of spermatozoa occurs in :-
(1) Neck (2) Head (3) Middle piece (4) Tail

6. Function of mitochondria in the sperm is :-
(1) to produce energy for the movement of tail
(2) for sperm maturation
(3) for axial filament formation
(4) to contain enzymes for fertilisation

7. 'Spermiogenesis' is a process in which :-
(1) spermatids are changed into spermatozoa
(2) spermatogonium produces a spermatid
(3) spermatocytes give rise to spermatozoa
(4) dormant spermatozoa become active just before ejaculation

8. During oogenesis, the small structure separated from egg is :-
(1) polar bodies (2) primary oocyte (3) oogonia (4) germinal cell

9. In gametogenesis, reduction division take place during :-
(1) Multiplication phase (2) Growth phase
(3) First maturation division (4) Second maturation

10. Which cell organelle is absent in Ovum?
(1) Nucleus (2) Cell membrane (3) Mitochondria (4) Centriole

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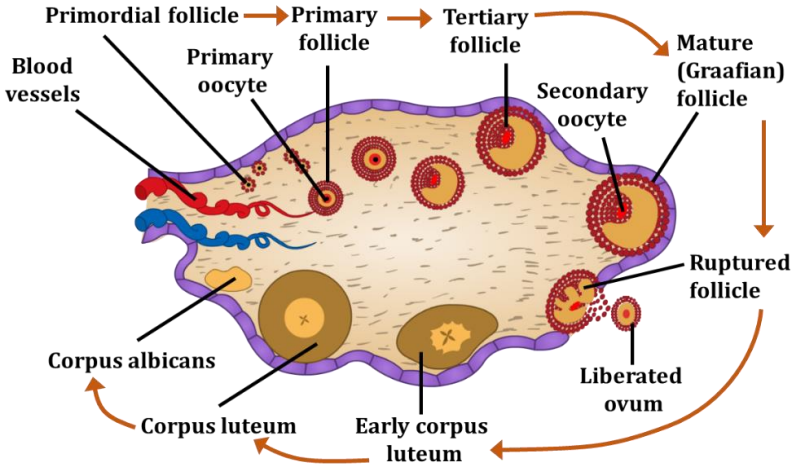
11. 10 oogonia yield 10 primary oocytes, then how many ova are produced on completion of oogenesis ?
(1) 5 (2) 10 (3) 20 (4) 40

12. The minute cells which separate from the developing ova during their maturation are called as:-
(1) primary oogonia (2) secondary oogonia
(3) polar bodies (4) primary spermatogonia

13. How many polar bodies are produced during the entire process of oogenesis in unmarried/virgin human female ?
(1) Three (2) Two (3) One (4) Four

5. Structure of Ovary :



- Outer most layer of ovary is called germinal epithelium while the inner layer called T. albuginea is made up of White fibrous connective tissue.
- The inner part of ovary is called as stroma. it is differentiated into 2 parts; outer peripheral part is cortex & inner part is called medulla. Stroma consists of follicular cells, connective tissues, blood vessels & lymphatics.
- Numerous oogonia are found in cortical region in intrauterine life and thousands of follicles are found in cortical region at puberty.

6. Formation of Ovarian or Graafian Follicle :

Ova develop from oogonia present in the cortex of the ovary. The oogonia are surrounded by other cells that form a stroma for them. These stromal cells form the ovarian or Graafian follicle that surrounds the ovum and protects it.
The stages is formation of Graafian follicle are as follows :

(A) Primordial Follicle : (Developing primary follicle)

Some cells of the stroma become flattened and surround a primary oocyte (which develops from oogonia). These flattened cells ultimately form the ovarian follicle and are therefore called follicular cells.
The flattened follicular cells now become columnar. Follicles up to this stage of development are called primordial follicle.

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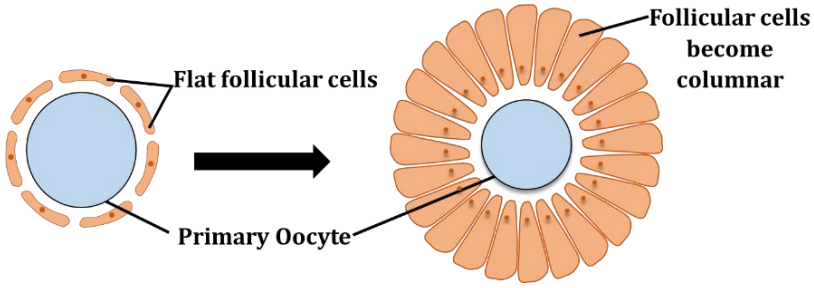
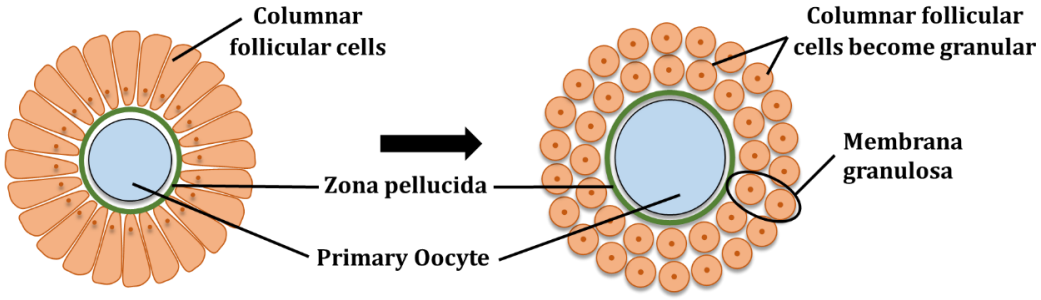


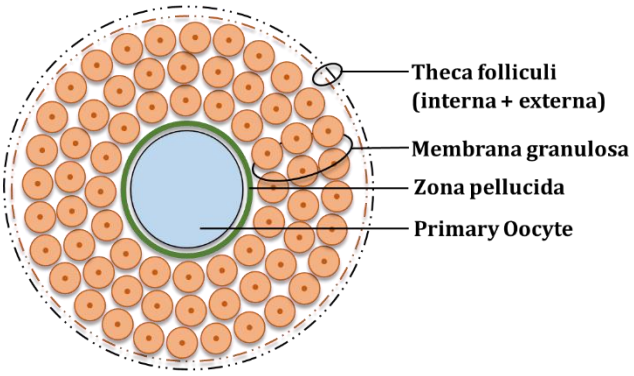
(B) Primary Follicle :

- A glycoprotein membrane called the zona pellucida, now appears between the follicular cells and the oocyte.
- The follicular cells proliferate now to form several layers of cells to form the membrane granulosa. These cells are now called granulosa cells, this stage of follicle primary follicle.
- Therefore, at puberty only 60,000-80,000 primary follicles are left in each ovary.



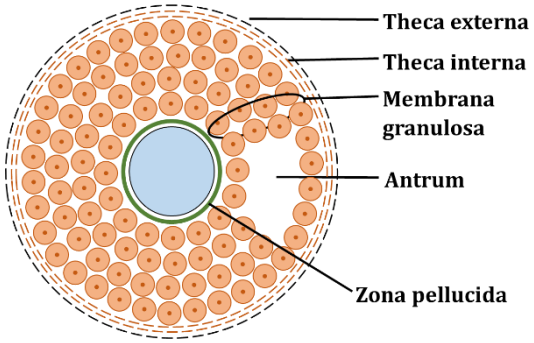
(C) Secondary Follicle :

- A new theca (Theca folliculi) is formed around the follicle because as more layers of granulosa cells are formed, the follicle expands and the stromal cells surrounding the membrana granulosa become condensed to form a covering called the Theca Interna.
- Outside the theca interna some fibrous tissue become condensed to form another covering called the Theca Externa.
- The cells of theca interna (Thecal cells) secrete a hormone called oestrogen.



(D) Tertiary Follicle :

- The secondary follicle soon transforms into a tertiary follicle which is characterised by a fluid filled cavity called **antrum** within the membrana granulosa.
- Theca layer is organised clearly into an inner theca interna and outer theca externa.



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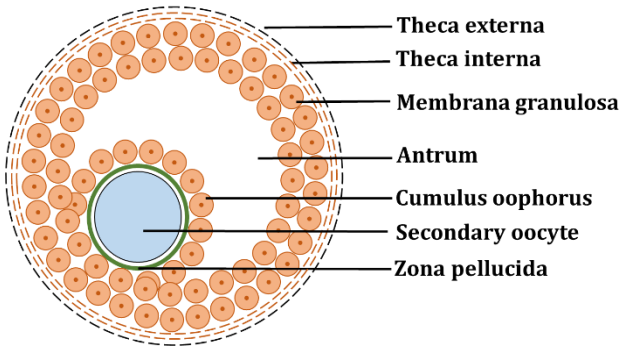
(E) Mature Tertiary Follicle/Graafian Follicle :

- The cavity of the follicle rapidly increases in size and gets filled with a fluid called liquor folliculi. Due to increase in the size of the cavity the wall of the follicle (formed by granulosa cells) becomes relatively thin.
- The oocyte now lies eccentrically in the follicle, surrounded by some granulosa cells that are called as cumulus oophoricus or oophorus.



- The ovarian follicle is now fully formed and is now called the Graafian Follicle.
- After 13 days of menstrual cycle (on 14th day when cycle is ideally for 28 days) Graafian follicle is ruptured & secondary oocyte (arrested in metaphase-II) or egg is released in peritoneal cavity.

Formation of Corpus Luteum :

- Before ovulation the inner side of follicle is avascular but soon after ovulation blood vessels grow into ruptured graafian follicle becomes filled with blood which is known as corpus heamorrhagicum. It is an initial stage of corpus luteum.
- The granulosa cells of ruptured graafian follicle proliferate and these cells become yellow due to accumulation of pigment called lutein. These cells are called lutein/luteal cells. Lutein cells secrete progesterone. Estrogen is also secreted by corpus luteum.

Fate of Corpus Luteum :

- Progesterone hormone maintains pregnancy and repairs the wall of uterus to make its surface adhesive to help in implantation.

Fertilization ⟹ Implantation

NO	YES
Corpus luteum starts degenerating after about 9 days of its formation (23rd day of m.cycle) and converted into corpus albicans about 28th day of m. cycle. **Corpus albicans** does not secrete any hormone	Corpus luteum become stable for next nine months by the help of hCG secreted by embryonic cells (trophoblast or blastocyst)

Follicular Atresia :

- **Few million follicles** are present in each fetal ovary but a large number of these follicles degenerate during the phase from birth to puberty. Therefore, **at puberty only 60,000-80,000 primary follicles are left in each ovary.**
- This degeneration of ovarian follicles is termed as follicular atresia. This is responsible for limited number of gamete production in females.

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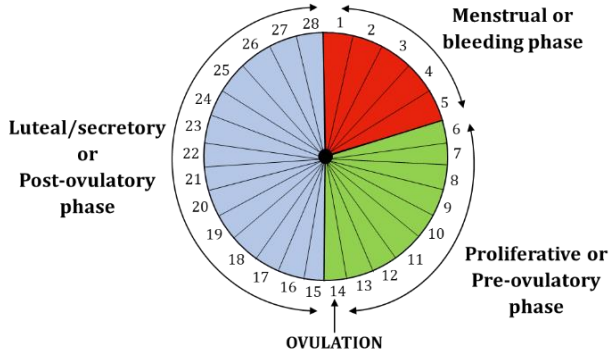
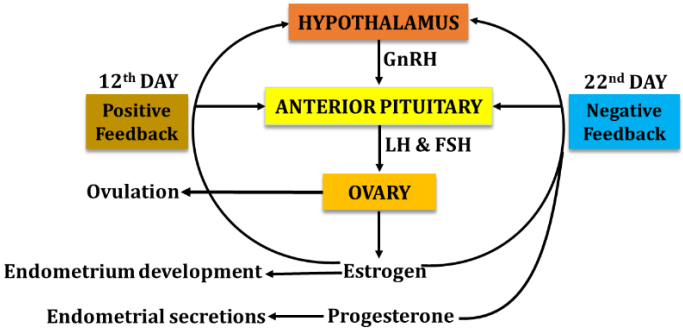
- Generally, only one ovum is liberated in each menstrual cycle, by alternate ovaries. Although most of the follicular cells and the oocytes undergo degeneration during follicular atresia, some thecal cells, formed from the stroma and located around the follicle, persist and become active. These are called interstitial cells. These cells secrete small amount of androgen.
- Only about 450 egg are produced by a human female over the entire span of her reproductive life which lasts till about 50 years of age.

7. Menstrual Cycle :

- **The reproductive cycle in the female primates (e.g. monkeys, apes and human beings) is called menstrual cycle. The first menstruation begins at puberty and is called menarche.**
- **In human females, menstruation is repeated at an average interval of about 28/29 days, and the cycle of events starting from one menstruation till the next one is called the menstrual cycle.**
- In Menstrual cycle the female body prepares itself for a possible pregnancy. If the pregnancy does not occur, then the body aborts all preparation done and restarts the preparation for pregnancy again in a monthly cyclic manner.
- Menstrual cycle has three main phases:
  - **(i) Bleeding phase or menstruation phase.**
  - **(ii) Proliferative/preovulatory/follicular phase or oestrogenic phase.**
  - **(iii) Secretary/post ovulatory/luteal phase or progesteronic phase.**





	Estrogen		Progesterone (Anti-abortion or Pregnancy hormone)
1.	Endometrial hyperplasia.	**1.**	Increases secretory nature of endometrium (Development of glands)
2.	Increases vascularity of endometrium	**2.**	Increases adhesive nature of endometrium.
3.	Myometrial hypertrophy.	**3.**	Decreases myometrial contraction.
4.	Ultimately increase thickness of uterine wall.	**4.**	Maintains thickness of uterine wall.

Hormone Levels	Ovarian changes	Uterine changes
1. BLEEDING PHASE (4–5 DAYS)		
On day 1 of the cycle, levels of all four hormones (FSH, LH, estrogen and progesterone) are low.	Initially corpus luteum/corpus albicans (of previous cycle) disintegrates completely.	Due to withdrawal of sex hormones, prostaglandins are formed in uterus which cause vasoconstriction. It leads to decreased blood supply to ***stratum functionalis*** that results in its degeneration and separation.
Due to absence of negative feedback of estrogen and progesterone, levels of FSH and LH start increasing in terminal stage of this phase.	Then 6-12 primary follicles are stimulated for further follicular development.	Prostaglandins also cause contractions in myometrium which leads to sloughing of dead endometrial tissue (stratum functionalis) with blood from uterine cavity through vagina. This bleeding continues for 4-5 days, and clotting does not occur due to presence of fibrinolytic enzymes. *Average 40 to 80 ml blood loss per cycle.*

Hormonal changes	Ovarian changes	Uterine changes
2. FOLLICULAR/PROLIFERATIVE/ESTROGENIC/PREOVULATORY PHASE		
The secretion of gonadotropins (LH and FSH) increases gradually. Level of estrogen in the blood continues to rise throughout most of this phase, reaching a maximum (peak) in terminal stage of this phase.	During this phase, the primary follicles in the ovary grow to become a fully mature Graafian follicle. [1-2 secondary follicles $\rightarrow$ 1 tertiary follicle $\rightarrow$ 1 Graafian follicle] Follicular development is stimulated by increasing secretion of gonadotropins. Growing follicles secrete estrogen.	Uterine bleeding is stopped. Endometrial hyperplasia. i.e. formation of stratum functionalis.
Due to positive feedback of this high level of estrogen, both LH and FSH attain a peak level in about middle of cycle. Progesterone level remains low until just before ovulation.	Swelling of Graafian follicle due to increase in antral fluid. Maximum level of LH during the mid-cycle called LH surge and due to this synthesis of proteolytic enzymes resulting in rupturing of Graafian follicle and ovarian wall resulting in ovulation.	Myometrial hypertrophy i.e. increase in size of myometrial cells. Thickness of uterine wall is increased.

- During ovulation, only one ovum is released per menstrual cycle.
- Only about 450 ova are produced by a human female over the entire span of her reproductive life.

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Hormonal changes	Ovarian changes	Uterine changes
LUTEAL/SECRETORY/PROGESTERONIC/POST-OVULATORY OR FIX PHASE (14 days)		
The levels of progesterone and estrogen rise up to about middle of this phase.	Ruptured graafian follicle ↓ Corpus hemorrhagicum ↓ Corpus luteum (maximum developed on 22nd day)	Due to increased progesterone endometrium becomes secretory (glandular) and adhesive.
In the absence of fertilisation (pregnancy), levels of these two hormones start declining from about middle of this phase onwards.	Degeneration of corpus luteum into corpus albicans begins about 9 days of ovulation to form Corpus albicans (on 28th day) and it does not secrete any hormone.	Due to progesterone and estrogen, the thickness of uterine wall is further increased. On day 23 of menstrual cycle, the thickness of uterine wall is maximum.
The presence of progesterone and estrogen in this phase results in negative feedback on both FSH and LH secretion. Because of this negative feedback, the levels of FSH and LH are relatively low in this phase.	No new follicles are developed in this phase.	In the absence of fertilisation (pregnancy), due to declining level of estrogen and progesterone, the thickness of uterine wall decreases in terminal stage of this phase.

- During pregnancy all events of the menstrual cycle stop and there is no menstruation.
- Menstruation only occurs if the released ovum is not fertilised. Lack of menstruation (= amenorrhoea) may be indicative of pregnancy. However, it may also be caused due to some other underlying causes like stress, poor health etc.
- **Dysmenorrhoea:** Painful menstruation is called Dysmenorrhoea.
- **Polymenorrhoea:** In polymenorrhoea or epimenorrhoea, the menstrual cycle is reduced from the normal of twenty-eight days to a cycle of two to three weeks and remains constant at that increased frequency.

- Lack of menstruation may be indicative of pregnancy. However, it may also be caused due to some other underlying causes like stress, poor health etc.
- In human beings, menstrual cycles begin from approx. **13 years** of age; that is termed as menarche and menstrual cycles cease around **50 years** of age; that is termed as menopause. Cyclic menstruation is an indicator of normal reproductive phase.

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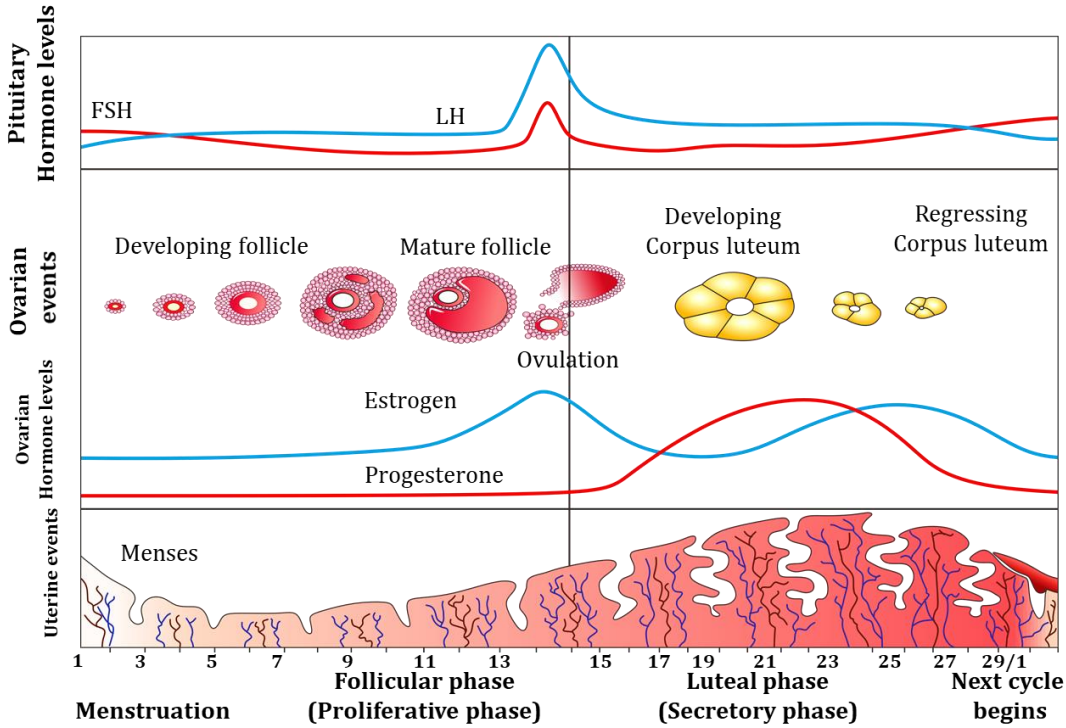

Menstrual Hygiene :

- Maintenance of hygiene and sanitation during menstruation is very important. Take bath and clean yourself regularly. Use sanitary napkins or clean homemade pads. Change sanitary napkins or homemade pads after every 4-5 hrs as per the requirement. Dispose of the used sanitary napkins properly wrapping it with a used paper. Do not throw the used napkins in the drainpipe of toilets or in the open area. After handling the napkin wash hands with soap.

BEGINNER'S BOX-4 — INTERNAL STRUCTURE OF OVARY AND FOLLICULAR DEVELOPMENT & MENSTRUAL CYCLE

1. Number of eggs released in the life time of a woman is approximately :-
(1) 40 (2) 400 (3) 4000 (4) 20000

2. Corpus luteum develops from:-
(1) oocyte (2) nephrostome (3) Graafian follicle (4) antrum

3. First menstrual cycle starts at:-
(1) parturition (2) menopause (3) puberty (4) implantation

4. Menstrual cycle is generally of:-
(1) 21 days (2) 28 days (3) 38 days (4) 40 days

5. Which of the following hormones control (s) the menstrual cycle in human beings ?
(1) FSH (2) LH
(3) FSH, LH, estrogen (4) only progesterone

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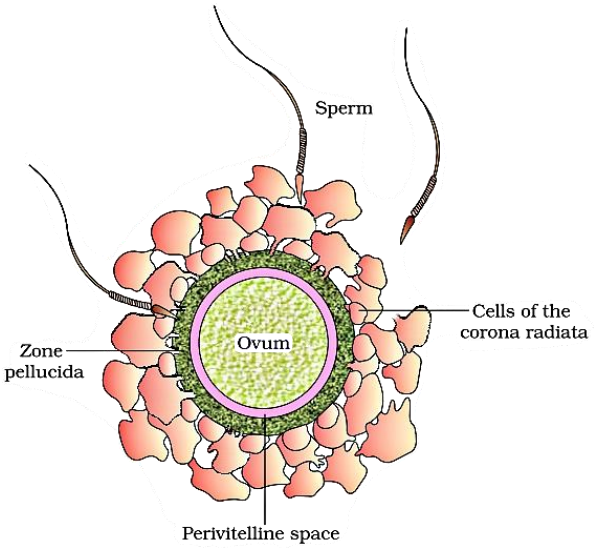
8. Structure of Human Egg :

- Oocyte/ovum is surrounded by membranes termed as the egg-membranes. Oocyte / Ovum along with the egg-membrane are termed as the egg.
- On basis of origin, egg-membranes are of 3 types :

(i) **Primary Egg Membrane:** This membrane is secreted by the oocyte itself.
Example: Zona Pellucida (mammals).

(ii) **Secondary Egg Membrane:** This is found outside the primary egg membrane and is secreted by the ovary. Example: Corona radiata

(iii) **Tertiary Egg Membrane:** This is present outside the primary egg membrane. It is either secreted by the uterus or the oviduct.
Example: Jelly coat in amphibians & Shell in terrestrial oviparous animals.



Functions of Egg-membranes

- To provide protection
- To check polyspermy
- To provide buoyancy to the amphibian eggs

9. Fertilisation :

- The process in which union of male and female gametes (formed by gametogenesis) and fusion of pronuclei of sperm and ovum takes place thus diploid zygote is formed, is called **fertilisation**.
- The motile sperms swim rapidly, pass through the cervix, enter into the uterus and finally reach the **ampullary region** of the fallopian tube. The ovum (secondary oocyte) released by the ovary is also transported to the ampullary region where fertilisation takes place. Fertilisation can only occur if the ovum and sperms are transported simultaneously to the ampullary region. This is the reason why not all copulations lead to fertilisation and pregnancy.
- The union of male and female gametes is called **Syngamy**.
- Intermixing of their cytoplasm is called plasmogamy.
- The fusion of pronuclei of sperm and ovum is called **karyogamy**.
- The intermingling of their chromosomes is called **amphimixis**.

Mechanism of Fertilization :

1. Movement of sperms towards the secondary oocyte.

2. Penetration of corona radiata by the hyaluronidase enzyme.

3. Adherence of sperm to the ZP3 receptors/region on zona pellucida, this leads to initiation of acrosomal reaction. Various enzymes are released. E.g. Acrosin (Zona lysin).

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4. Acrosin facilitate the penetration of sperm through zona pellucida.
5. Fusion of sperm and membrane of secondary oocyte. (Syngamy).
6. Phagocytosis of sperm by the secondary oocyte.
7. Completion of meiosis-II of secondary oocyte during phagocytosis to form ovum and simultaneously it releases 2nd polar body.
8. Structural changes in zona pellucida through cortical reaction and discharge of cortical granules in perivitelline space forms fertilization membrane, which prevent polyspermy.
9. In the event of fertilization complete sperm enters inside the ovum. (By phagocytosis)
10. It is followed by plasmogamy in which all the structures of sperm dissolve in egg cytoplasm except sperm nucleus and proximal centriole (this centriole will help in cleavage after formation of zygote).
11. The nucleus of sperm absorbs water from egg cytoplasm and becomes enlarged. Now it is called male pronucleus.
12. Male pronucleus and female pronucleus migrate through definite routes and come close to each other. These routes are called fertilization path.
13. This is followed by karyogamy and amphimixis i.e. completion of fertilization.

Significance of Fertilisation :

1. Secondary oocyte completes its second maturation division before completion of fertilization on coming in contact with the sperm.
2. Amphimixis process leads to the formation of a diploid zygote to restore the normal diploid number of the chromosomes.
3. The centriole of sperm after entering into egg induces the egg to undergo cleavage.
4. The paternal and maternal characters are transmitted to the offspring through the process of fertilisation.
5. The peripheral changes occurring in the egg membrane prevent the further entry of sperm into the ovum, thus checking polyspermy.
6. The male gametes (sperms) the sex chromosome could be either X or Y, hence, 50 per cent of sperms carry the X chromosome while the other 50 per cent carry the Y. After fusion of the male and female gametes the zygote would carry either XX or XY depending on whether the sperm carrying X or Y fertilised the ovum. The zygote carrying XX would develop into a female baby and XY would form a male.

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BEGINNER'S BOX-5 STRUCTURE OF HUMAN EGG & FERTILISATION

1. Secondary egg membrane is formed by :-
(1) oocyte (2) ovary (3) oviduct (4) uterus

2. In human, egg is fertilised in :-
(1) ovary (2) fallopian tube (3) uterus (4) vagina

3. Fertilisation is :-
(1) fusion of diploid spermatozoon with diploid ovum to form diploid zygote
(2) fusion of haploid sperm with haploid ovum to form haploid zygote
(3) fusion of haploid sperm with haploid ovum to form diploid zygote
(4) fusion of diploid sperm with haploid ovum to form triploid zygote

4. Sperm differs from egg in :-
(1) having power of motility (2) having no stored food
(3) production in more numbers (4) All of these

5. Intermixing of cytoplasm of sperm and egg is known as :-
(1) Syngamy (2) Plasmogamy
(3) Karyogamy (4) Amphimixis

10. Cleavage (Cellulation or Segmentation) :

- The term 'Cleavage' was given by "Von Baer".
- In fertilised egg or activated egg, the egg undergoes repeated cell divisions which occur rapidly producing a multicellular structure without changing its size. All these rapid mitotic cell divisions are collectively called cleavage or segmentation.
- Due to the process of cleavage, a single celled zygote, through a successive mitotic cell divisions changes into a complex multicellular structure. Cells produced as a result of cleavage are termed as blastomeres.
- The cleavage starts as the zygote moves through the isthmus of the oviduct towards the uterus.

	Cleavage	Normal Mitosis
(1)	Newly formed cells are known as blastomeres	Newly formed cells are known as daughter cell
(2)	Interphase is short, only 'S' phase is present	Interphase is long G, S, G_2 phase are present

Classification of Cleavage :

On the basis of fate of blastomere

Determinate cleavage	Indeterminate cleavage
The fate of blastomere is fixed, determined i.e blastomere forms a particular portion of embryo e.g. Nematoda, annelida, mollusca	The fate of blastomere is not definite. These are totipotent in early stage of embryo. e.g. Human

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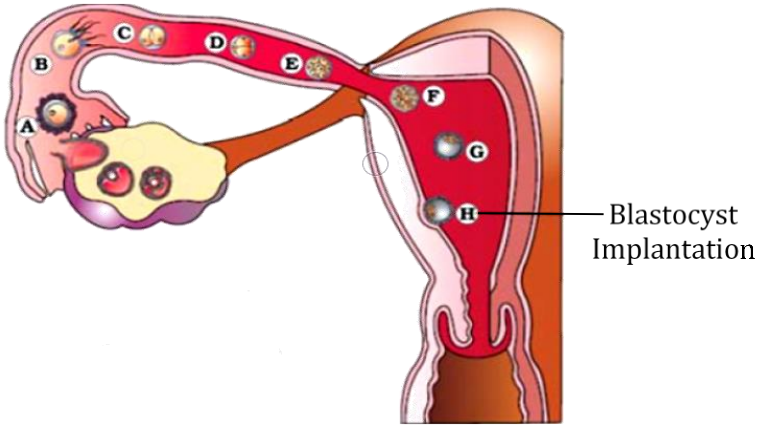
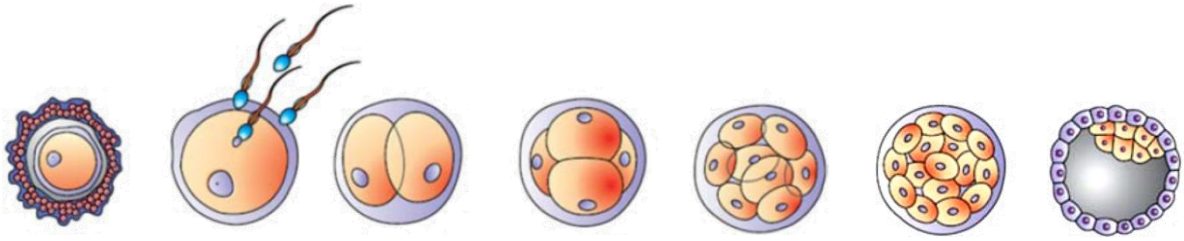
11. Implantation, Pregnancy & General Stages of Embryonic Development :

(A) Morulation :

- As a result of segmentation or cleavage activities, unicellular zygote changes into a solid ball like multicellular structure. In the later stage of cleavage, clusters of sticky, cohering, protruding (outside) blastomeres are produced, which look like mulberry. This stage is termed as morula stage. The embryo with 8 to 16 blastomeres is called a morula.





(a)	(b)	(c)	(d)	(e)	(f)	(g)
Egg	Fertilization	2 Cells	4 Cells	Morula 8 cells	Morula 16 cells	Blastula 32-64 Cells

(B) Blastulation :

- The morula continues to divide and transforms into blastocyst. Blastula of eutherian and metatherian mammals is called blastocyst, because blastula is in the form of a cyst.
- The blastomeres in the blastocyst are arranged into an outer layer called trophoblast and an inner group of cells attached to trophoblast called the inner cell mass. The trophoblast layer then gets attached to the endometrium and the inner cell mass gets differentiated as the embryo.
- In human being, the blastocyst gets attached with the uterine endometrium in about four days after entering in uterus.
- **After attachment, cells of trophoblast secrete some enzymes which helps the embryo enter in the endometrium. The uterine cells divide rapidly and covers the blastocyst. By 12th day after fertilization, blastocyst is completely buried in the wall of the uterus. This is called implantation and it leads to pregnancy.**
- In human, the site of implantation is generally mid-dorsal/fundus part of uterus.

(C) Gastrulation :

- In gastrula stage rate of cleavage division is slow and ultimately stops at the end of gastrula. Gastrula stage is the most important stage in embryonic development because formation of three germinal layers i.e. ectoderm, mesoderm and endoderm takes place.
- During gastrulation, Inner Cell Mass differentiates into an outer layer called **ectoderm** and an inner layer called **endoderm**. **Mesoderm** soon appears between the ectoderm and the endoderm. These three layers give rise to all tissues (organs) in adults.

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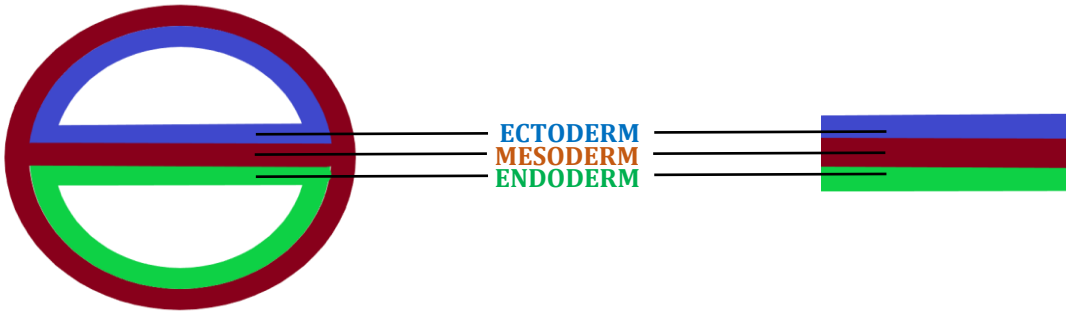
- It needs to be mentioned here that the inner cell mass contains certain cells called **stem** cells which have the potency to give rise to all the tissues and organs.



Summary of Developmental Stages in Human :

- After one month of pregnancy, the embryo's heart is formed.
- By the end of the second month of pregnancy the foetus develops limbs and digits.
- By the end of 12 weeks (First trimester), most of the major organ system are formed.
- The first movements of the foetus and appearance of hair on the head are usually observed during the fifth month.
- By the end of 24 weeks (Second trimester), the body is covered with fine hair, eye-lids separate and eye lashes are formed.
- By the end of nine months of pregnancy, the foetus is fully developed and is ready for delivery.

Extra Embryonic Membranes :

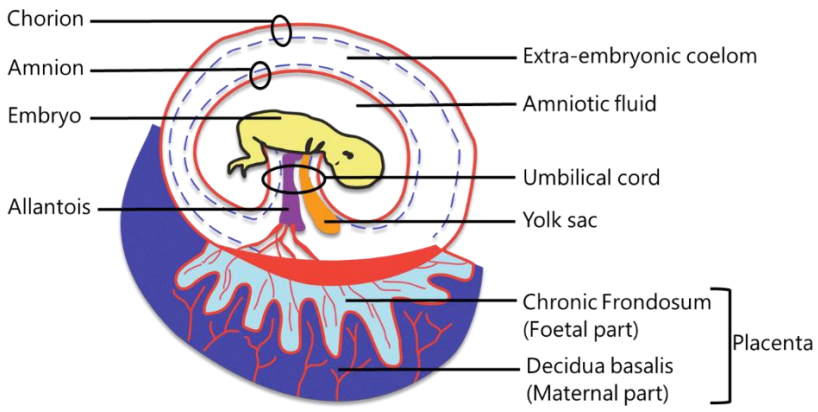
Extra embryonic membranes are of four types–

(i) **Amnion:** Cells of amnion secrete amniotic fluid in which foetus remains hanging. Amniotic fluid prevents it from desiccation.

(ii) **Chorion:** After implantation of blastocyst, the trophoblast gives out several finger like processes, the chorionic villi which get embedded into uterine endometrium

(iii) **Yolk Sac:** About eight weeks after fertilization, the yolk sac is reduced in size and changes into a tubular structure. Yolk sac is the 1st haematopoietic organ of embryo.

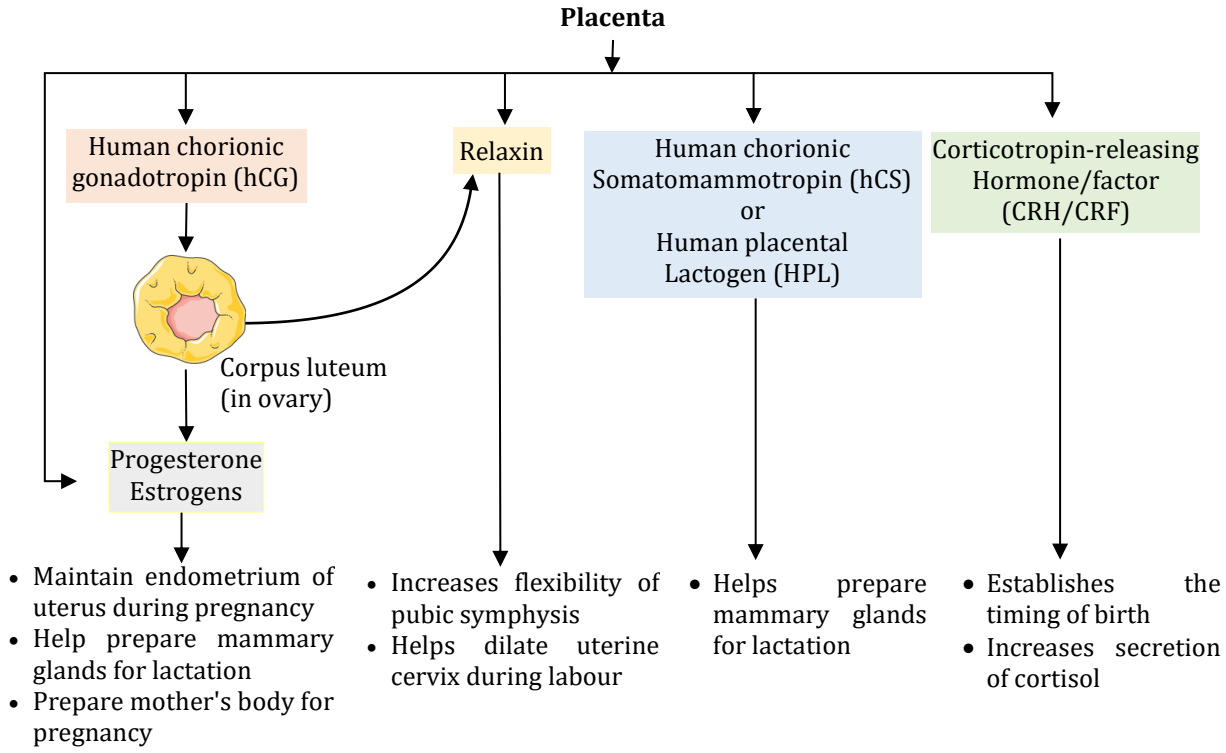
(iv) **Allantois:** Allantois forms many small blood vessels. These vessels connect the embryo with placenta and ensure nutritional and respiratory supply to embryo. In human, allantois does not function to store the excretory wastes as it does in reptiles, birds and prototherians.



12. Placenta :

- The chorionic villi and uterine tissue become interdigitated with each other and jointly form a structural and functional unit between developing embryo (foetus) and maternal body called placenta.
- The embryo depends upon maternal tissues for shelter, nutrition, respiration etc.
- Placenta is found in viviparous animals.
- Placenta is temporary endocrine structure which partially derive from maternal and embryonic tissue.

Hormones of Placenta :


Placenta
Human chorionic gonadotropin (hCG)
Relaxin
Human chorionic Somatomammotropin (hCS) or Human placental Lactogen (HPL)
Corticotropin-releasing Hormone/factor (CRH/CRF)
Corpus luteum (in ovary)
Progesterone
Estrogens
• Maintain endometrium of uterus during pregnancy
• Help prepare mammary glands for lactation
• Prepare mother's body for pregnancy
• Increases flexibility of pubic symphysis
• Helps dilate uterine cervix during labour
• Helps prepare mammary glands for lactation
• Establishes the timing of birth
• Increases secretion of cortisol

Functions of Placenta :

1. Exchange of important materials between foetal and maternal blood.
2. The essential materials are exchanged by diffusion, pinocytosis or active transport.
3. The small molecules like O_2, CO_2, H_2O etc. are diffused through placenta.
4. Placenta serves as a respiratory medium for exchange of O_2 and CO_2 between embryo and mother.
5. The nutritional substances are supplied to embryo from the mother through placenta.
6. The nitrogenous and metabolic wastes from foetus are released into the blood of mother by diffusion through placenta.
7. The antibodies (**IgG**) for measles, chickenpox, polio etc. present in the blood of mother reach the embryo through placenta.
8. If a female takes some harmful chemicals (teratogens), liquor, drugs etc. during pregnancy, these may cross the placenta and on reaching into foetus may cause deformity during organogenesis. (e.g. Thalidomide)
9. Placenta acts as temporary endocrine structure.

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10. It secretes some hormones like progesterone, estrogen, inhibin, hCG, hCS/HPL etc. HCG maintains the corpus luteum. Progesterone, maintains and supports the foetus during the whole pregnancy period.
11. At the time of parturition, relaxin is secreted by placenta which lubricates, and widens the birth canal to facilitate childbirth.

Note: During pregnancy the levels of other hormones like estrogens, progestogens, cortisol, prolactin, thyroxine, etc., are increased several folds in the maternal blood.

13. Parturition And Lactation :

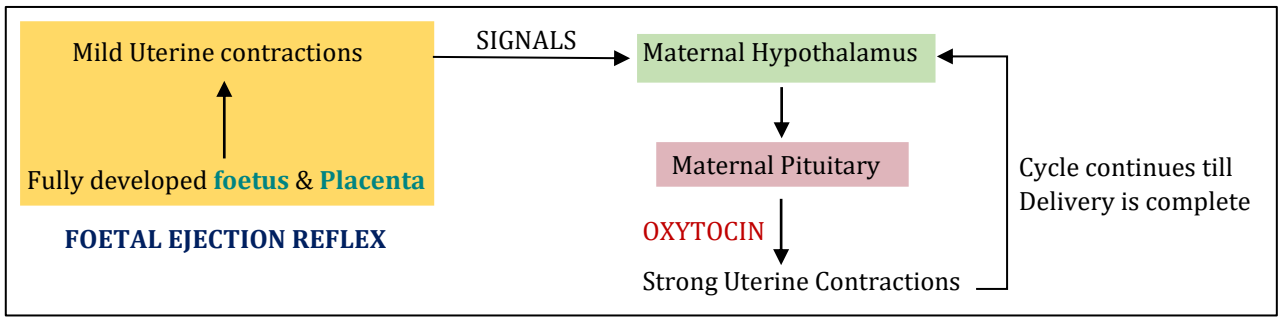
- The average duration of human pregnancy is about 9 months which is called the gestation period. Vigorous contraction of the uterus at the end of pregnancy causes expulsion/delivery of the foetus. This process of delivery of the foetus (childbirth) is called **parturition**.
- The process of childbirth is called parturition which is induced by a complex neuroendocrine mechanism involving cortisol, estrogens and oxytocin. Many hormonal changes take place during it.
- By the end of pregnancy mammary glands start producing milk by a process called lactation.

Foetal Ejection Reflex :

- The signals for parturition originate from the fully developed foetus and the placenta which induce mild uterine contractions called foetal ejection reflex.

Parturition :

- As a result of mild uterine contractions, maternal pituitary gland secretes Oxytocin. This hormone induces intense contractions in the uterus. Due to these contractions, the foetus starts moving towards the vagina. The labour pain during child-birth, is due to this hormone. Oxytocin is the main parturition hormone.
- After parturition, Oxytocin stimulates milk-let down by milk ejection reflex.
- During parturition, Relaxin hormone is secreted by the placenta and the ovary of pregnant female. This hormone relaxes the pubic-symphysis i.e. the joint between the pelvic-girdles. So more space is available to the foetus to move out.



Lactation :

- The mammary glands of the female undergo differentiation during pregnancy and starts producing milk towards the end of pregnancy by the process called lactation.
- This helps the mother in feeding the new- born. The milk produced during the initial few days of lactation is called colostrum which contains several antibodies absolutely essential to develop resistance for the new-born babies.
- Breast-feeding during the initial period of infant growth is recommended by doctors for bringing up a healthy baby.

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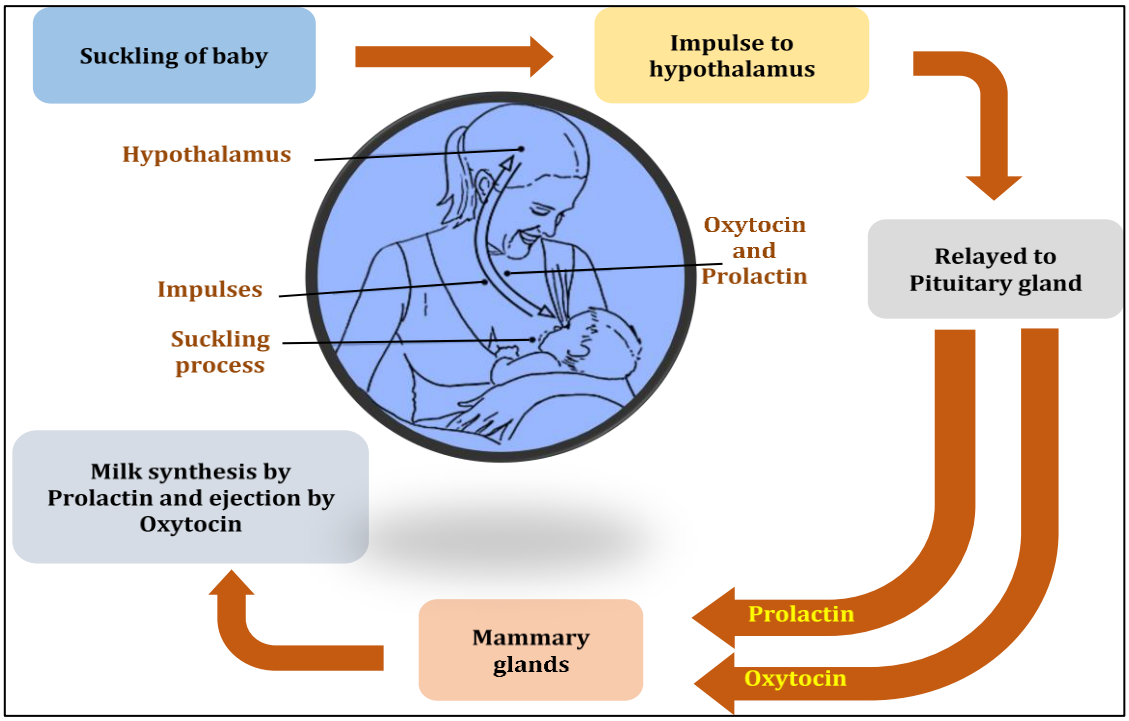

EXTRA POINTS

- The age of reproductive maturity is called puberty. Puberty occurs in males and females respectively at the age of 12-15 years and 11-14 years.
- Reproductive maturity is marked by a number of changes (/secondary sexual characteristics) in the body. Some examples of such changes / characteristics are:
- In male: Appearance of beard, moustache, pubic hairs; attraction for girls, voice of low pitch, etc.
- In female: Menarche, development of breasts (mammary glands), appearance of pubic hairs, attraction for boys, voice of high pitch, etc.
- Testosterone and estrogen are essential for development and maintenance of reproductive structures and secondary sexual characteristics of male and female respectively.
- Homologous structures are derived embryologically from the same tissue. Some of the homologous structures of male and female are as following :

	Male	Female
(1)	Scrotal sac	Labia majora
(2)	Penis	Clitoris
(3)	Prostatic utricle	Vagina, Uterus
(4)	Prostate gland	Paraurethral gland of Skene
(5)	Bulbourethral gland	Bartholin's gland

- Orchidectomy means surgical removal of testes.
- Oophorectomy means surgical removal of ovaries.
- Hysterectomy means surgical removal of uterus.
- Salpingectomy means surgical removal of one or both fallopian tubes.
- Development of unfertilised ovum into a new individual is known as parthenogenesis.

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- In human, cleavage divisions are unequal holoblastic (on the basis of amount of yolk) and of indeterminate type (on the basis of fate of blastomeres).
- Pattern of cleavage is affected by change in amount of yolk and its distribution in the egg.
- Twins are of two types :
  (1) When two ova are released and each is fertilized by a different sperm, fraternal twins are produced. These twins are dizygotic (the products of two different zygotes) and can be the same or different sex. Fraternal twins are non-identical and are as different from each other as are non twin brothers and sisters.
  (2) Identical twins occur when an early embryo divides into two. These twins are monozygotic (derived from one zygote) and are identical genetically. Rarely, identical twins are conjoined (i.e. they fail to separate completely during embryonic development). These are called Siamese twins.

Golden Key Points

- Pathway of transport in spems in male reproductive system:
  Seminiferous tubules → Straight tubule → Rete testis → Vasa efferentia → Epididymis → Vas deferens → Ampulla → Ejaculatory duct → Urethra → Out (through urethral meatus)
- Sertoli cells are stimulated/regulated by FSH hormone.
- Inhibin suppresses mainly the FSH synthesis.
- Sequence of spermatogenic stages in a mature human testis:
  Spermatogonium(2n) → Primary spermatocyte(2n) → Secondary spermatocytes(n) → Spermatids(n) → Sperms(n)
- Entry of sperm induces the completion of the meiotic division of the secondary oocyte. The second meiotic division is also unequal and results in the formation of a second polar body and a haploid ovum (ootid).
- Withdrawal of estrogen and progesterone(mainly) hormones is the cause of menstruation.
- Maximum level of LH during the mid-cycle called LH surge induces rupture of Graafian follicle and thereby the release of ovum (ovulation).
- Corpus luteum secretes hormones like progesterone, estrogen, inhibin. In the later phase of pregnancy, a hormone called relaxin is also secreted by the ovary (corpus luteum).
- In a normal pregnant female, high level of hCG stimulates the synthesis of estrogen and progesterone.
- Multiple changes that activate the sperm for the final processes of fertilisation are collectively called capacitation. These occur in sperm on coming in contact with the fluids of the female genital tract.
- Placenta produces several hormones like human chorionic gonadotropin (hCG), human placental lactogen (hPL), estrogen, progesterone, relaxin, etc.
- The signals for parturition originate from the fully developed foetus and the placenta.
- Increase in estrogen and progesterone ratio is an important component of initiation of parturition in human.
- Oxytocin is a hormone secreted by posterior pituitary. Oxytocin acts on the uterine muscle and causes stronger uterine contractions during parturition.

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BEGINNER'S BOX-6

CLEAVAGE, EMBRYONIC DEVELOPMENT & PARTURITION

1. Formation of three germinal layers is significance of :
(1) morula stage (2) blastocyst stage (3) gastrula stage (4) all these stages

2. Movement of blastomeres usually seen in which embryonic stage ?
(1) Morula (2) Blastocyst (3) Gastrula (4) In all embryonic stages

3. The first movements of the foetus and appearance of hair on the head are usually observed during the :-
(1) 3rd month (2) 4th month (3) 5th month (4) 8th month

4. Parturition is induced by :-
(1) a complex neuroendocrine mechanism (2) a neural mechanism
(3) a neuro exocrine mechanism (4) a physiochemical mechanism

5. Which hormone is secreted in women only during the pregnancy ?
(1) Progesterone (2) hPL (3) Estrogen (4) Thyroxin

BEGINNER'S BOX — ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	3	4	2	1	1	1	2	2	2	3
	Que.	11	12	13	14						
	Ans.	4	3	3	1						

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	4	3	2	2	2	4	1	2	3	4
	Que.	11	12	13	14						
	Ans.	4	4	3	4						

BEGINNER'S BOX-3	Que.	1	2	3	4	5	6	7	8	9	10
	Ans.	1	3	1	4	2	1	1	1	3	4
	Que.	11	12	13							
	Ans.	2	3	3							

BEGINNER'S BOX-4	Que.	1	2	3	4	5	
	Ans.	2	3	3	2	3	

BEGINNER'S BOX-5	Que.	1	2	3	4	5	
	Ans.	2	2	3	4	2	

BEGINNER'S BOX-6	Que.	1	2	3	4	5	
	Ans.	3	3	3	1	2	

ESSENCE

1.
- Humans are sexually reproducing and viviparous. The sexes are separate.

2.
- The male reproductive system is composed of a pair of testes, the male sex accessory ducts and the accessory glands and external genitalia.
- The testes are situated outside the abdominal cavity within a pouch called scrotum.
- Each testis has about 250 compartments called testicular lobules, and each lobule contains one to three highly coiled seminiferous tubules.
- The male sex accessory ducts include tubuli recti, rete testis, vasa efferentia, epididymis and vas deferens.
- The male accessory glands include paired seminal vesicles, a prostate and paired bulbourethral glands.
- Seminal plasma along with the sperms constitute the semen.
- The male external genitalia is called penis.
- Each seminiferous tubule is lined inside by spermatogonia and sertoli cells. The spermatogonia undergo meiotic divisions leading to sperm formation, while sertoli cells provide nutrition to the dividing germ cells. The Leydig cells outside the seminiferous tubules, synthesise and secrete testicular hormones called androgens.

3.
- The female reproductive system consists of a pair of ovaries, a pair of oviducts, a uterus, a vagina, external genitalia, and a pair of mammary glands.
- The ovaries produce the female gamete (ovum) and some steroid hormones (ovarian hormones).
- The oviducts, uterus and vagina are female accessory ducts.
- Each oviduct (or fallopian tube) has three parts namely infundibulum, ampulla and isthmus.
- Upper, expanded part of uterus is called body or fundus and lower, narrower part of uterus is called cervix. The wall of uterus has three layers namely perimetrium, myometrium and endometrium.
- The female external genitalia includes mons pubis, labia majora, labia minora, clitoris, vestibule and hymen.
- The mammary glands are one of the female secondary sexual characteristics. Mammary glands differentiate during pregnancy and secrete milk after child-birth.

4.
- Spermatogenesis results in the formation of sperms that are transported by the male sex accessory ducts.
- A normal human sperm is composed of a head, neck, a middle piece and tail.
- The process of formation of mature female gametes is called oogenesis.

5.
- Ovarian follicles in different stages of development are embedded in the stroma.

6.
- The reproductive cycle of female primates is called menstrual cycle.
- Menstrual cycle starts only after attaining sexual maturation (puberty).
- The cyclical changes in the ovary and the uterus during menstrual cycle are induced by changes in the levels of pituitary and ovarian hormones.
- During ovulation only one ovum is released per menstrual cycle.

7.
- Zona pellucida and corona radiata are two egg membranes of human egg.

8.
- After coitus, sperms are transported to the junction of the isthmus and ampulla, where the sperm fertilises the ovum leading to formation of a diploid zygote.
- The process of fertilisation has four main events namely syngamy, plasmogamy, karyogamy and amphimixis.
- The presence of X or Y chromosome in the sperm determines the sex of the embryo.

9.
- The zygote undergoes repeated mitotic division to form a blastocyst, which is implanted in the uterus resulting in pregnancy.
- After nine months of pregnancy, the fully developed foetus is ready for delivery.

10.
- The process of childbirth is called parturition which is induced by a complex neuroendocrine mechanism involving cortisol, estrogens and oxytocin.
- The new-born baby is fed milk by the mother (lactation) during the initial few months of growth.